Washington State
Department of Transportation

SR 108 MP 7.62 Unnamed Tributary to Skookum Creek: Preliminary Hydraulic Design Report

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SR 108 Unnamed Tributary – Remove Fish Barrier
MP 7.62 Unnamed Tributary to Skookum Creek
Preliminary Hydraulic Design Report
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1.0 Introduction and Purpose

To comply with United States, et al vs. Washington, et al No. C70-9213 Subproceeding No. 01-1 dated March 29, 2013 (a federal permanent injunction requiring the State of Washington to correct fish barriers in Water Resource Inventory Areas (WRIAs) 1-23), the Washington State Department of Transportation (WSDOT) is proposing a project to provide fish passage at the SR 108 crossing of Unnamed Tributary to Skookum Creek at Mile Post (MP) 7.62. This existing structure on SR 108 has been identified as a fish barrier by Washington Department of Fish and Wildlife (WDFW) and WSDOT Environmental Services Office (ESO) (Site ID 991672) due to a water surface drop at the outlet. Per the injunction, and in order of preference, fish passage should be achieved by (a) avoiding the necessity for the roadway to cross the stream, (b) use of a full span bridge, or (c) use of the stream simulation methodology. WSDOT evaluated design options as defined in the injunction. Avoidance of the stream crossing was determined to not be viable given the location of the highway and the need to maintain this critical transportation corridor. WSDOT is proposing to replace the existing crossing structure with a structure designed using the bridge design methodology.

The structure is located in Mason County 3.9 miles southwest of Kamilche, WA in Water Resource Inventory Area (WRIA) 14. The highway runs east-west at this location, while the Unnamed Tributary generally flows southeast to northwest beginning approximately 4,900 feet upstream of its crossing with SR 108 and discharging into Skookum Creek approximately 1,600 feet downstream of the crossing. Skookum Creek generally flows west to east and joins the Little Skookum Inlet approximately 5.2 miles downstream of the confluence with the Unnamed Tributary. See Figure 1 for the vicinity map.

The proposed project will replace the existing 53 feet long, 60-inch diameter bituminous-lined corrugated metal pipe culvert with a minimum 28 foot span structure to improve fish passage while providing a safe roadway for the traveling public. This proposed structure is designed to meet the requirements of the federal injunction utilizing the bridge design criteria outlined in the 2013 WDFW Water Crossing Design Guidelines (WCDG).

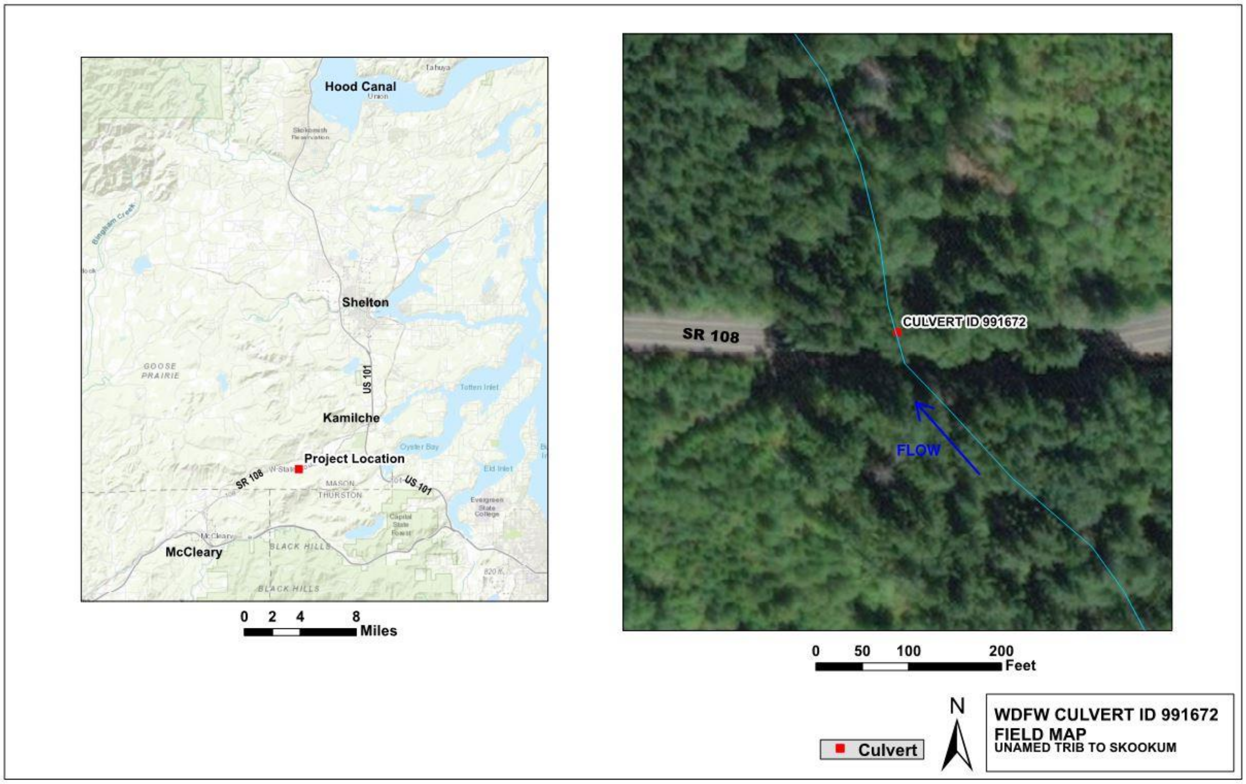


Figure 1 Vicinity map

2.0 Site Assessment

Osborn Consulting, Inc. (OCI) and HDR conducted a site visit on August 23, 2019 to visually assess the stream and collect information to support the design of the Unnamed Tributary to Skookum Creek. The team walked the stream from approximately 300 feet upstream of the inlet to approximately 300 feet downstream of the outlet of the existing 60-inch diameter bituminous-lined corrugated metal culvert. The following provides a description of field observations moving from upstream to downstream.

Upstream of the existing culvert, the stream corridor is densely vegetated with large trees, grasses and shrubs. The stream channel is moderately incised with more evidence of incision at the upstream extent of the survey area. Bank heights varied from 8 feet at approximately 300 feet upstream of the culvert inlet to 2 feet just upstream of the culvert inlet (Figure 2).

Figure 2 Typical channel (Left) and Bank erosion (Right) upstream of existing culvert

A small amount of flow was encountered approximately 300 feet upstream of the culvert, but no discernable flow was observed in the majority of the stream channel between this location and the culvert inlet. The streambed substrate appears to be poorly sorted with a mixture of cobbles and gravels. Multiple wood accumulations were observed in the upstream reach with high potential for wood recruitment.

Two bankfull width measurements were taken in the upstream reach, approximately 200 feet and 300 feet upstream of the existing culvert inlet, which measured 14 feet and 14.6 feet, respectively (Figure 3).

Figure 3 Bankfull width location 200 feet upstream of existing culvert (Left) and 300 feet upstream of existing culvert (Right)

The stream banks and roadway embankment are armored with riprap just before the culvert inlet (see Figure 4). Based on the 2005 WDFW Fish Passage and Diversion Screening Inventory Database (FPDSI) Report, the culvert to stream width ratio is 0.69 and the roadway fill depth is 1.6 feet.

Figure 4   SR 108 Culvert inlet

There is a large scour hole downstream of the culvert outlet, creating a drop of approximately 3 feet to the assumed water surface elevation (See Figure 5). Large riprap is present in the channel bed from below the culvert outlet to approximately 20 feet downstream of the culvert outlet. At this point there is an approximate 5-foot drop from the crest of the riprap to the streambed.

Figure 5   SR 108 culvert outlet scour hole (Left) and drop downstream of culvert outlet (Right)

The reach downstream of the existing culvert is highly incised with evidence of significant bank erosion and root scour (see Figure 6). The streambed has incised and armored itself with cobbles. The stream channel is nearly twice as wide as the channel upstream of the existing culvert with measurements up to 22 feet wide. The stream gradient appears to be relatively high just downstream of the culvert outlet, gradually decreases along the downstream reach, then increases again approximately 300 feet downstream of the culvert. Bank heights range from approximately 12 to 15 feet throughout the downstream reach.

Figure 6 Typical channel in downstream reach showing bank erosion

During the initial site visit, there was no discernable flow observed in the downstream reach. Large cobbles were observed to be present just downstream of the existing culvert, but the streambed substrate decreases in size to smaller cobbles and gravels moving downstream. There is a significant amount of wood accumulation within the stream channel in the downstream reach with high potential for wood recruitment due to the bank erosion.

3.0 Watershed Assessment

3.1 Watershed & Landcover

The Unnamed Tributary flows in a generally northwesterly direction and joins Skookum Creek approximately 1,600 feet downstream of the existing SR 108 crossing. Skookum Creek drains into the Little Skookum Inlet near Kamilche, which flows into Totten Inlet and eventually into the Puget Sound. The drainage area to the tributary at the existing SR 108 culvert crossing is 0.61 square miles delineated based on LiDAR data using GIS ArcHydro tools. The average mean annual precipitation is 79.0 inches/year (PRISM). The basin is primarily comprised of evergreen forest based on ESRI aerial imagery and 2016 NLCD land cover data, with smaller pockets of deciduous and mixed forest. The southeast corner of the basin consists of shrub/scrub land and grassland due to logging activities. Figure 7 shows a map of the basin boundary.

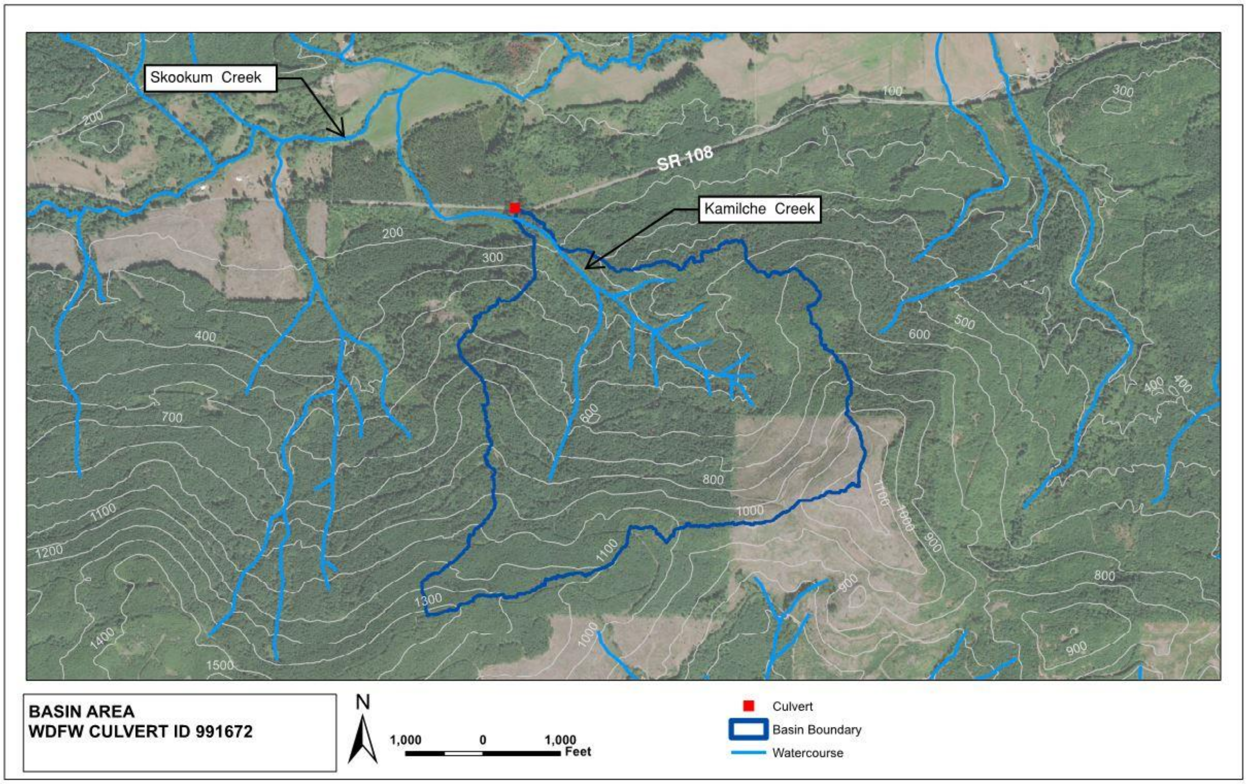


Figure 7 Basin boundary

3.2 Mapped Floodplains

The existing SR 108 culvert is located in Zone X, an area of minimal flood hazard, based on FEMA Flood Insurance Rate Map (FIRM) 53045C0750E (Figure 8). The project site is located approximately 1,200 feet outside of the FEMA-mapped 100-year floodplain of Skookum Creek.

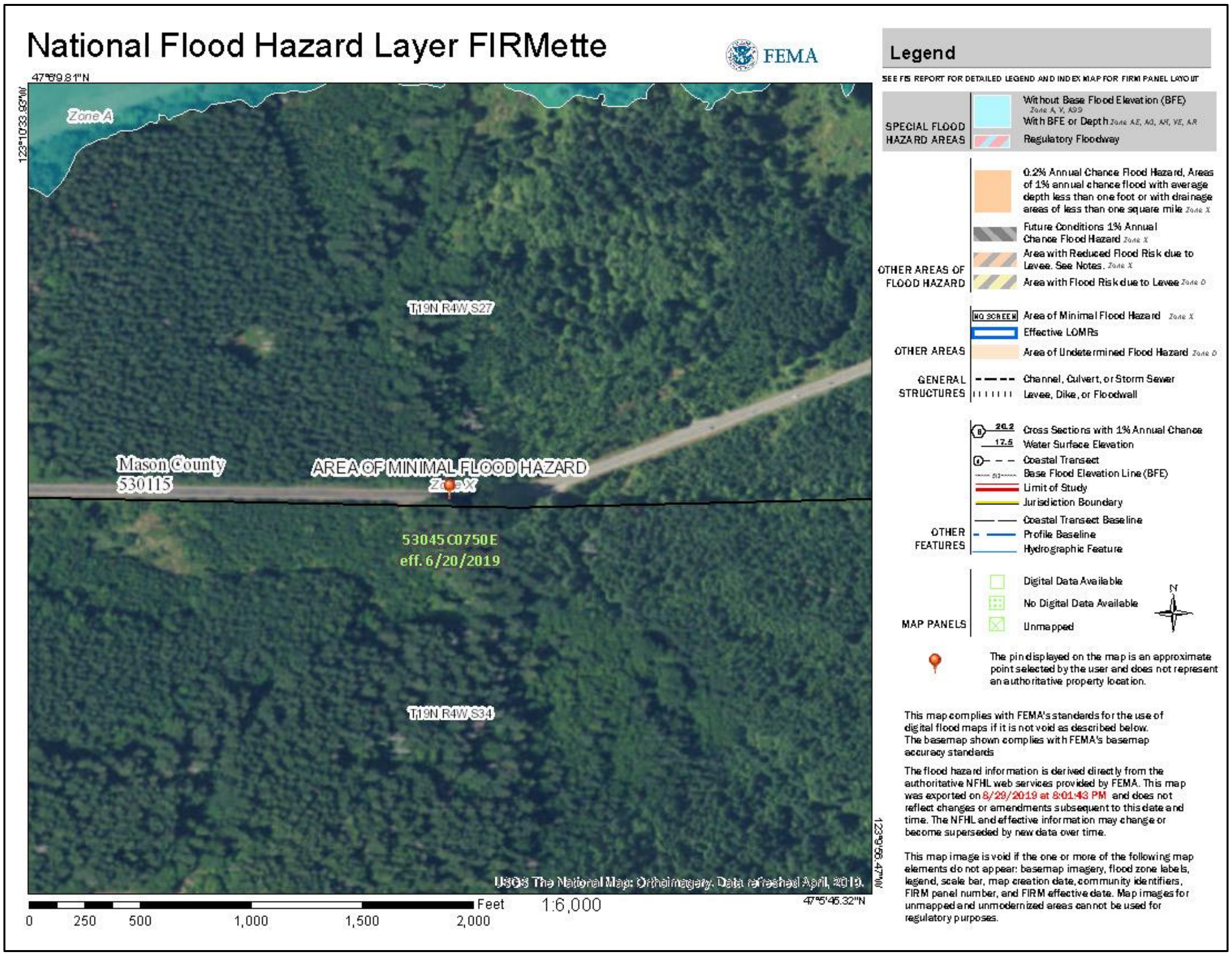


Figure 8 FEMA mapped floodplain (FIRM 53045C0750E)

3.3 Geology & Soils

The drainage basin to the Unnamed Tributary is underlain by continental glacial deposits including Vashon Stade till and outwash, Pre-Fraser Glaciation drift, and tertiary igneous rock of the Crescent Formation. The continental glacial deposits typically contain granitic and metamorphic rock and abundant polycrystalline quartz (Logan, 2003). The majority of the basin consists of Vashon Stade till (Qgt), Vashon Stade proglacial and recessional outwash (Qgo), and Crescent Formation basalt (Ev_c). A small area of Pre-Fraser Glaciation till and outwash sand and gravel (Qgp) is present near the confluence with Skookum Creek. Figure 9 shows a map of the geologic units in the basin based on DNR classifications. These geologic units are further described as follows:

> **(Ev_c) Crescent Formation basalt** – Tertiary igneous rock of lower to middle Eocene period; characterized by dark gray greenish tint, brown where weathered, reddish and variegated along altered contact zones.
>
> **(Qgo) Proglacial and recessional outwash, late Wisconsinan (Pleistocene epoch), Vashon Stade** - Continental glacial deposits of Fraser Glaciation; poorly to moderately sorted, rounded

gravel and sand with localized coarser- and finer-grained constituents; typically shades of gray where fresh or brown where stained

(Qgt) Till, late Wisconsinan (Pleistocene epoch), Vashon Stade – Continental glacial deposits of Fraser Glaciation; unsorted, unstratified, highly compacted mixture of clay, silt, sand, gravel, and boulders deposited by glacial ice; typically gray and may contain interbedded stratified sand, silt, and gravel

(Qgp) Drift - Continental glacial deposits of Pre-Fraser Glaciation; undifferentiated till and outwash sand and gravel of northern provenance; commonly oxidized or stained orange

Elevations within the basin range between approximately 170 feet to 1320 feet above sea level based on contours obtained from Mason County GIS. Most of the basin has steep slopes of 10-50%, and gentler slopes of 2-10% are present in some areas, particularly near SR 108.

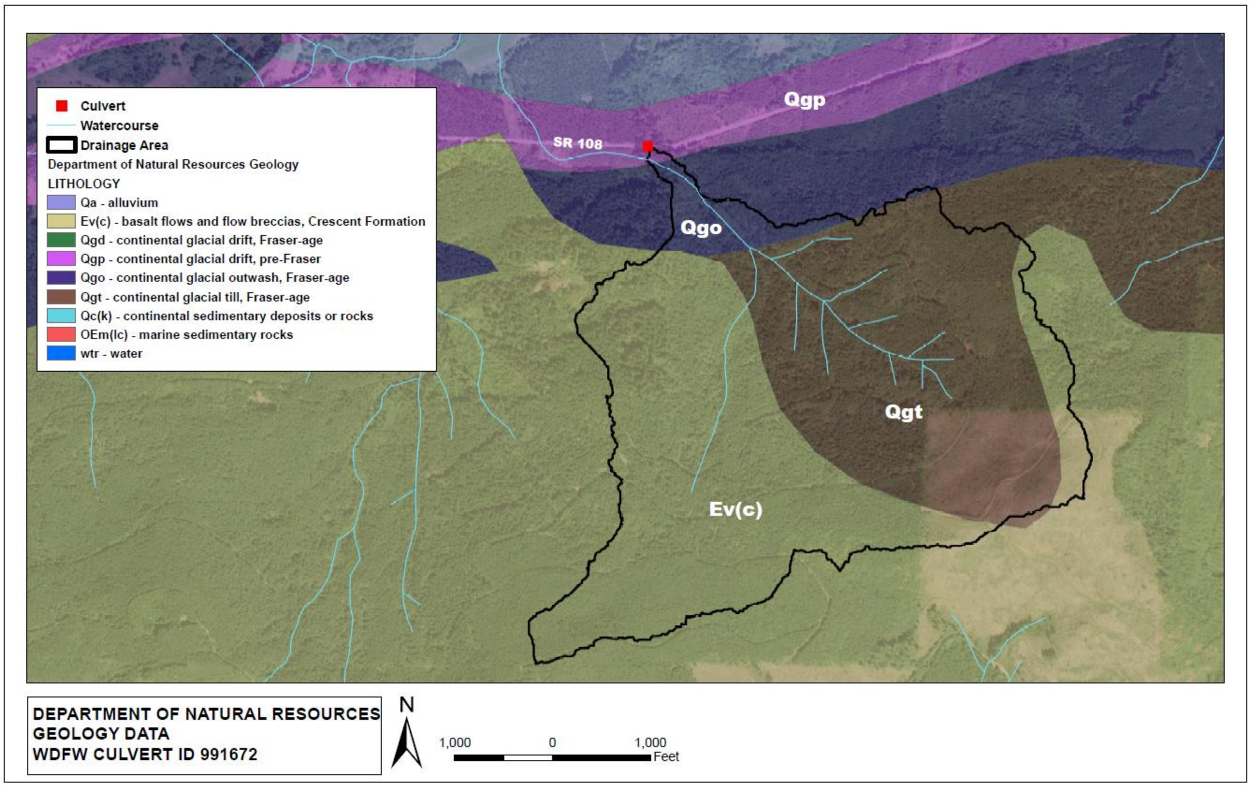
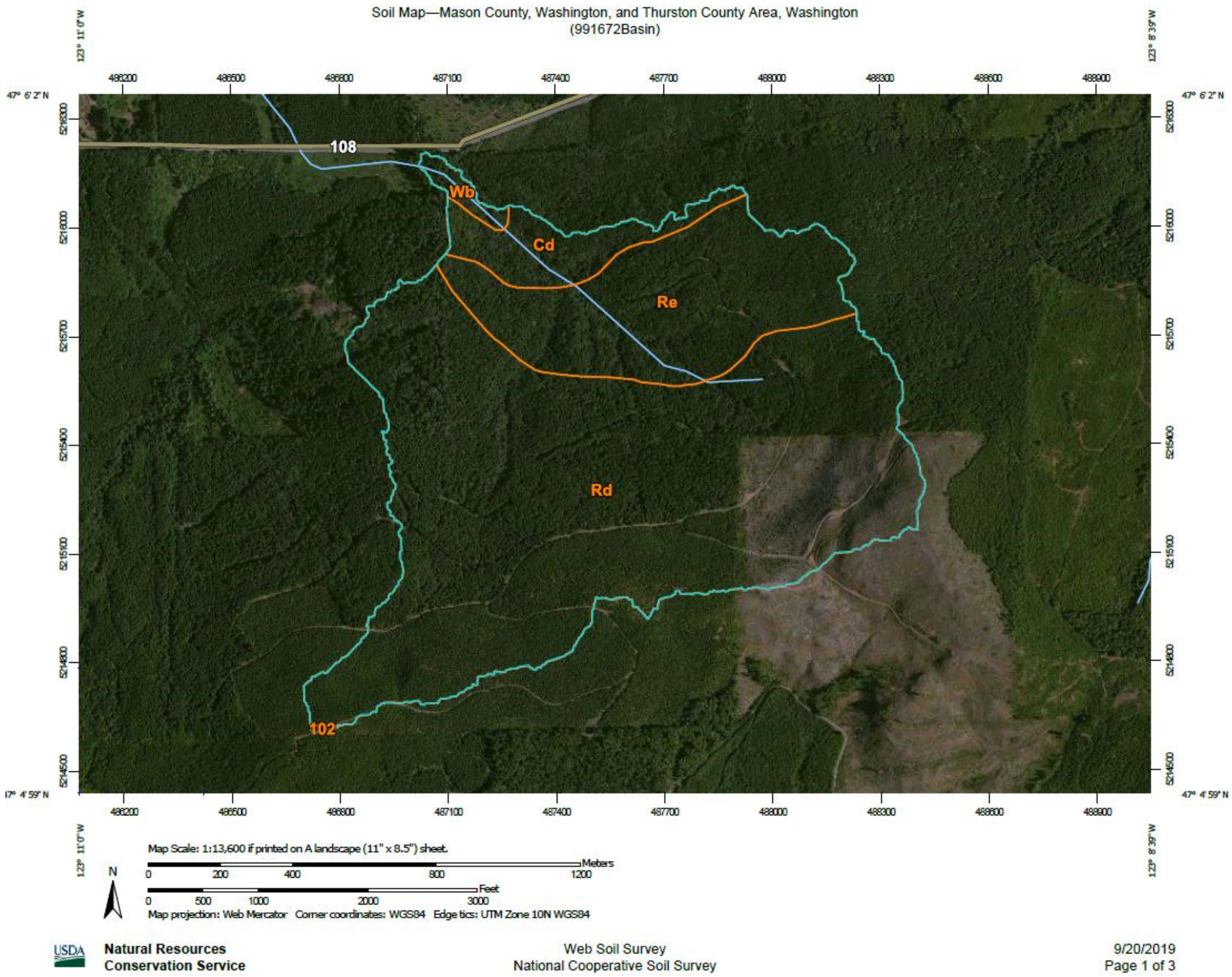


Figure 9 Surficial Geology (WA DNR Geologic Units 1:100,000 Scale)

Soils in the basin primarily include silt loam, gravelly loam, very gravelly loam, unweathered bedrock, Tebo soil material, and Tebo-Shelton complex. Tebo soil material is described as till derived from basalt consisting of silt loam to gravelly clay loam. Shelton soil material is described as basal till with volcanic ash consisting of very gravelly medial loam to very gravelly sandy loam. The hydrologic soil groups (HSG) of the soils within the basin are approximately 15% A, 43% B, 6% C, and 36% bedrock. These soils vary from well-drained with high infiltration rate (HSG A) to fine textured with slow infiltration rate (HSG C). Figure 10 shows a map and table of the soil units in the basin.



Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Cd	Cloquallum silt loam, 15 to 30 percent slopes	21.9	5.6%
Rd	Rough mountainous land, Tebo soil material	284.5	72.5%
Re	Rough mountainous land, Tebo-Shelton complex	81.8	20.8%
Wb	Wadell gravelly loam, 5 to 10 percent slopes	4.2	1.1%
Subtotals for Soil Survey Area		**392.3**	**99.9%**
Totals for Area of Interest		**392.5**	**100.0%**

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
102	Schneider very gravelly loam, 20 to 40 percent slopes	0.3	0.1%
Subtotals for Soil Survey Area		**0.3**	**0.1%**
Totals for Area of Interest		**392.5**	**100.0%**

Figure 10 NRCS Web Soil Survey

3.4 Geomorphology

3.4.1 Channel Geometry

The stream planform is relatively straight with mild meander bends. As no discernable flow was observed in stream at the time of the assessment, no clear riffles and pools were detected in the assessed portion of the stream. The stream gradient in the reach upstream of the SR 108 crossing is moderate, with a steeper gradient in the downstream reach (Figure 11). The stream gradient is relatively high just downstream of the culvert outlet, gradually decreases along the downstream reach, then increases again approximately 300 feet downstream of the culvert. The downstream channel is nearly twice the width of the channel upstream of the existing culvert.

Figure 11 Typical channel upstream (Left) and downstream of SR 108 crossing (right)

Two bankfull width measurements were taken approximately 300 feet and 200 feet upstream of the existing culvert inlet, which measured 14 feet and 14.6 feet, respectively (see photos in Section 2.0). A bankfull width measurement was not conducted in the downstream reach due to the assumed unnatural conditions.

Based on basin area (0.61 square miles) and annual precipitation (79.0 inches per year), the WDFW regression equation estimates the bankfull width to be 11.0 feet.

A long channel profile was developed from the 2019 survey data and 2005 Puget Sound Lowlands LiDAR data (Figure 12). Upstream of the project area and within the detailed survey, the average reach slope is 4 percent. The reach downstream of the survey is less steep, with an average slope of 3 percent.

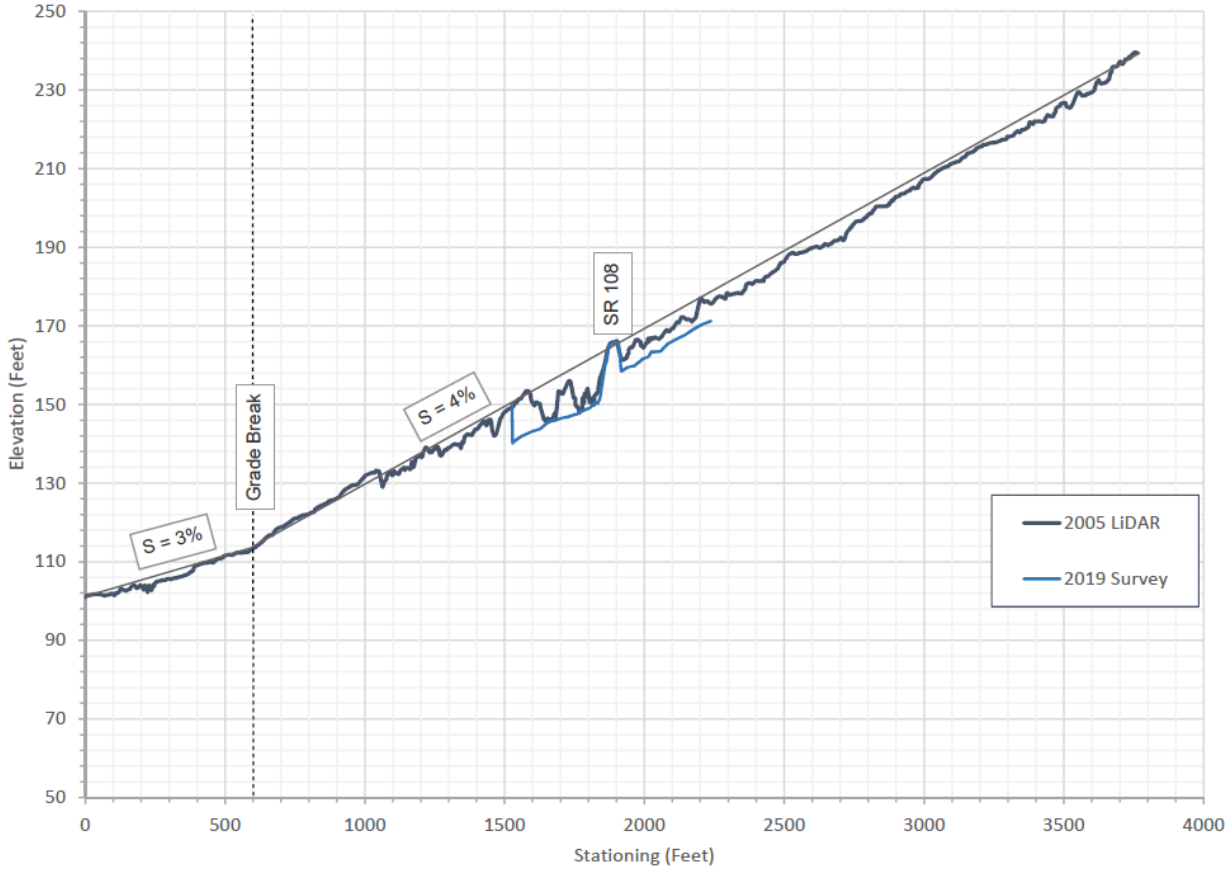


Figure 12 Long profile of UNT near SR 108 crossing

3.4.2 Potential for Aggradation, Incision and Headcutting

There are no signs of potential aggradation in the stream channel. Moderate incision was observed in the upstream reach with depth of incision varying from 5 to 8 feet. Significant incision was observed in the downstream channel with depth of incision varying from 12 to 15 feet. There is potential for the incision to continue over time.

The culvert outlet is perched above the streambed and is armored with large riprap from the outlet to approximately 20 feet downstream of the culvert. There is an approximate 5-foot drop at the end of the riprap to the streambed. The perched culvert and discontinuity in the channel grade observed in the downstream reach could potentially cause headcutting in the channel if removed.

3.4.3 Floodplain Flow Paths

The stream channel is incised both upstream and downstream of the culvert with bank heights ranging from 8 to 15 feet, indicating disconnection from the current floodplain due to incision. It is likely that most storm events stay in the channel and seldom overtop the banks.

3.4.4 Channel Migration

Opportunity for channel migration is relatively low as the channel appears to be confined, indicated by the moderate to high incision observed. Mature large woody vegetation on the banks suggests that the tributary has not experienced significant lateral movement recently. The land cover is largely forested and flows are not expected to change greatly if the basin remains undisturbed.

3.4.5 Existing LWM and Potential for Recruitment

In the stream reach upstream of the existing culvert, multiple wood accumulations were observed in the channel with high potential for wood recruitment. There is also a significant amount of wood accumulation within the downstream channel with high potential for wood recruitment due to the bank erosion. See Figure 13 and Figure 14for photos of wood accumulation in the channel.

Figure 13 Typical channel upstream of existing culvert showing wood accumulation

Figure 14 Typical channel downstream of existing culvert showing wood accumulation

3.4.6 Sediment Size Distribution

On August 29, 2019, three pebble count runs were performed in the reference reach, between bankfull width measurements 1 and 2. The streambed material at the pebble count location is shown in Figure 13. The grain size distribution is dominated by gravels and cobbles with a D_{50} of 2.12 inches, as summarized in Table 1. Figure 15 includes a picture of the typical substrate size observed. Figure 16 shows the cumulative distribution of sediment sizes at the location of the pebble count.

Figure 15 Streambed material photo upstream of SR 108 crossing

Table 1 Sediment properties downstream of SR 108 Crossing

Particle	Diameter (in)
D_{15}	0.63
D_{35}	1.47
D_{50}	2.12
D_{84}	4.22
D_{95}	5.81
D_{100}	10.08

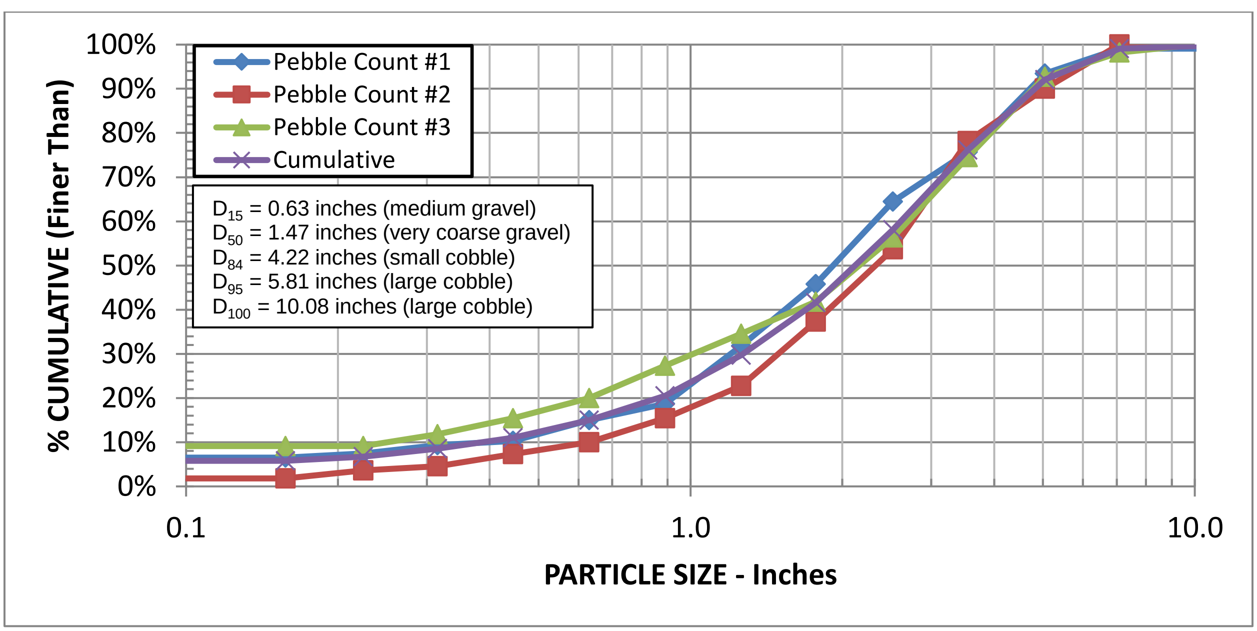


Figure 16 Wolman pebble count sediment size distribution

3.5 Groundwater

According to Washington State Department of Ecology (ECY) well logs and WDOE Environmental Information Management groundwater data, an in-stream piezometer (ID# ALP893) was installed in the Skookum Creek stream bed approximately 2500 feet west of the project site in 2004. The well was installed as part of Total Maximum Daily Load (TMDL) development efforts for segments of Skookum Creek. Stream depths and temperature were recorded but no groundwater level measurements were found for this well. The USGS National Water Information System groundwater monitoring database was also queried and no records were found for the site.

4.0 Fish Resources and Site Habitat Assessment

4.1 Fish Use

The portion of the Unnamed Tributary that is located within the project site supports the occurrence of fall-run coho salmon (*Oncorhynchus kisutch*), chum salmon (*Oncorhynchus keta*), winter-run steelhead (*Oncorhynchus mykiss*), and coastal cutthroat trout (*Oncorhynchus clarkii clarkii*) (WDFW PHS data 2019a; WDFW Salmonscape 2019b; Streamnet 2019). Of these species, winter steelhead that inhabit the watershed are part of the Puget Sound Distinct Population Segment (DPS) and are federally listed as threatened under the Endangered Species Act (ESA) of 1973. Besides salmonids, several additional fish species, including sculpin and lamprey, also inhabit the watershed. Table 2 provides a list of native fish potentially found in Skookum Creek and its tributaries. The creek was dry in the entire study reach at the time of the site visit in August 2019, and therefore no fish were observed.

Table 2 Native fish species potentially found

Species	Source (Assumed, Mapped, or Documented)	Pre-Existing Fish Use Surveys (spawner surveys or other biological observations)	Life History Present (Egg, Juvenile, Adult)	Limiting Habitat Factors	Stock Status and/or ESA Listing
Coho (*Onchorhynchus kisutch*)	Documented	Statewide Integrated Fish Distribution (SwIFD), Salmonscape, PHS	Juvenile, Adult	Spawning and Rearing	Not Warranted
Fall Chum (*Onchorhynchus keta*)	Documented	SwIFD, Salmonscape, PHS	Juvenile, Adult	Spawning and Rearing	Not Warranted
Winter Steelhead (*Onchoryhnchus mykiss*)	Documented	SwIFD, Salmonscape, PHS	Juvenile, Adult	Spawning and Rearing	Federally Threatened
Coastal Cutthroat (*Onchoryhnchus clarkii clarkii*)	Documented	SwIFD, Salmonscape, PHS	Egg, Juvenile, Adult	Spawning and Rearing	Not Warranted

Species	Source (Assumed, Mapped, or Documented)	Pre-Existing Fish Use Surveys (spawner surveys or other biological observations)	Life History Present (Egg, Juvenile, Adult)	Limiting Habitat Factors	Stock Status and/or ESA Listing
Sculpin (*Cottus*)	Assumed	None	Egg, Juvenile, Adult	Spawning and Rearing	Not Warranted
Lamprey (*Lampreta*)	Assumed	None	Egg, Juvenile, Adult	Spawning and Rearing	Not Warranted

4.2 Existing Habitat

Skookum Creek is a significant watershed in South Puget Sound, with numerous tributaries providing habitat for salmonids. Land use at higher elevations is predominately timber production, with livestock and pasture/hayfields in the mid and lower valleys. The Skookum Creek watershed provides spawning and rearing habitat for coho, chum, steelhead, and cutthroat trout throughout the mainstem and accessible reaches of its tributaries. These anadromous species are part of Puget Sound stocks and access Skookum Creek through the Little Skookum Inlet off Totten Inlet in South Puget Sound.

In addition to fish passage barriers in the upper watershed, the most significant biological impairments are habitat diversity and quantity, sediment load and transport, and summer water temperatures. The Unnamed Tributary that crosses SR 108 at MP 7.62 is a right bank tributary to Skookum Creek that provides rearing and migratory habitat for salmonids and other fish species.

4.2.1 Immediate Crossing

The current crossing is undersized for the channel and classified as a barrier to fish passage due to an excessive hydraulic drop at the culvert outlet. Coho, chum, and steelhead are not known to migrate above the culvert, particularly at low flows. The barrier condition of the culvert is assumed to be precluding both adult and juvenile salmon use of reaches upstream.

4.2.2 Quality Within Reach

Downstream of the SR 108 culvert crossing, the Unnamed Tributary flows through a deeply incised, high gradient channel with eroded banks over 10 feet in height. The riparian habitat consists of a mixed canopy of Douglas fir (*Pseudotsuga menziesii*) and some cedars (*Thuja plicata*), as well as alder (*Alnus rubra*) and big leaf maple (*Acer macrophyllum*). Ferns and shrubs including dogwood (*Cornus nuttallii*) and Indian plum (*Oemleria cerasiformis*) dominate the understory at the top of banks. The mature forest and shrub cover provides good shading, nutrient inputs, and some potential large woody material (LWM) recruitment. There were about five pieces of LWM observed in the downstream reach, where trees had fallen into the deep wide channel or across the top of the banks.

At the culvert outlet there is a large scour hole, creating a drop of approximately 3 feet, and a steep cascade formed by large rip rap. The streambed substrate downstream of this scour hole is comprised predominantly of cobbles, with some gravel and soil in areas at the base of the steep banks. Habitat in this reach is predominantly suited to seasonal migration, with little to no refuge areas for rearing juveniles. The stream channel was dry at the time of the site visit in August 2019.

The confluence with Skookum Creek is located approximately 0.3 miles downstream of the culvert crossing. Skookum Creek continues for approximately 5.7 miles to where it enters Little Skookum Inlet, and on to Totten Inlet off Puget Sound.

Upstream of the SR 108 crossing, the Unnamed Tributary flows through a mature mixed forested area comprised primarily of fir, alder, and big leaf maple, with some large cedars. There is a dense shrub understory with native and non-native species including salmonberry (*Rubus spectabilis*), Indian plum, vine maple (*Acer circinatum*), and some Himalayan blackberry (*Rubus armeniacus*). The mature forest and shrub cover provides good shading, nutrient inputs, and LWM recruitment. There were multiple areas that had LWM, including large conifer logs that had fallen across and within the channel which provided good in-stream habitat.

The stream gradient in the reach upstream of the SR 108 crossing appears lower than the downstream reach. The substrate was dominated by gravel and cobble throughout the upstream reach. The reach was completely dry during the August 2019 site visit. Habitat in this reach is good during seasonal flow periods and provides migratory, rearing, and some potential spawning habitat.

4.2.3 Length of Potential Gain

In January of 2008, WDFW surveyed 1.45 miles (7,628 feet) of the Unnamed Tributary upstream of the project site. They reported that the stream gradient likely precludes most upstream use by chum salmon. The survey ended at a 13 foot high cascade/falls that poses a natural barrier to further upstream fish passage (WDFW report 991672). The surveyed reach was documented as providing 0.9 acres of potential spawning habitat, and 0.4 acres of rearing habitat (WDFW report 991672).

4.2.4 Other Barriers in System

Currently there is a single passage barrier at a culvert located upstream of the project reach of the Unnamed Tributary. The mapped fish passage barrier is a culvert crossing under a forest road (site ID 994753). The WDFW survey report from 2008 for this crossing lists it as a complete barrier due to its slope.

Downstream of the crossing under SR 108, the Unnamed Tributary flows northward for approximately 0.3 miles and enters the right bank of Skookum Creek. There are no barriers mapped downstream of the project crossing. Skookum Creek then flows roughly eastward and crosses under both SR 108 and US 101 before entering Little Skookum Inlet. These crossings are bridges; there are no fish passage barriers in Skookum Creek downstream of the project crossing.

Figure 17presents a map of lower Skookum Creek, the Unnamed Tributary, and the fish passage features that were documented by WDFW during their fish passage inventory and habitat surveys.

4.2.5 Other Restoration Efforts in System

Commercial timberlands dominate the headwaters and upper watershed, while agricultural pasturelands, rural residential and urban development make up the majority of the valley floor through the lowlands.

The Squaxin Island Tribe owns portions of land in the lower reaches of Skookum Creek and its tributaries as it runs through the reservation. The Tribe, along with conservation groups have several completed and ongoing restoration and preservation projects in the Skookum Creek watershed. Tribal restoration projects in the watershed have improved freshwater habitat for salmonids, particularly for the coho run. Where Skookum Creek runs through Tribal property, the Squaxin Island Tribe has set aside 150-foot buffers on each side of the creek to protect ecological functions, and has begun replanting efforts.

The Tribe has also worked with the South Puget Sound Salmon Enhancement Group to dig out the steep, eroded banks of the lower creek. Instead of the near vertical 10-foot wall that previously existed, the streambank is now a gentle slope and creates floodplain connectivity. Additionally, the partners are building logjams to recreate natural conditions of in-stream habitat to help create pools where adult salmon can rest while migrating upstream and rearing juveniles can find refuge.

Work has been undertaken to place additional wood in the tributaries, with substantial LWM and key pieces being added to Reitdorf Creek, a left-bank tributary to Skookum Creek, in 2002 with the use of helicopters. McDonald Creek is the focus of two proposed Family Forest Fish Passage Program projects, each removing previous partial barriers upstream of the SR 108 crossing.

The Washington Wildlife and Recreation Coalition is working in partnership with the Squaxin Island Tribe to help acquire and permanently protect 158 acres of wetlands and shorelines along Skookum Creek, using grant funding for the Skookum Valley Wetland Acquisition. The Squaxin Island Tribe’s plans to buy up to 614 acres in the Skookum Valley, depending on landowners’ willingness. This project will protect more than 4 miles of Skookum Creek and an additional 4.4 miles of tributaries, as well as a number of wetlands, stream banks, and forests.

Though there have been restoration efforts on Skookum Creek and other tributaries, there are no known completed or planned future restoration efforts on this tributary.

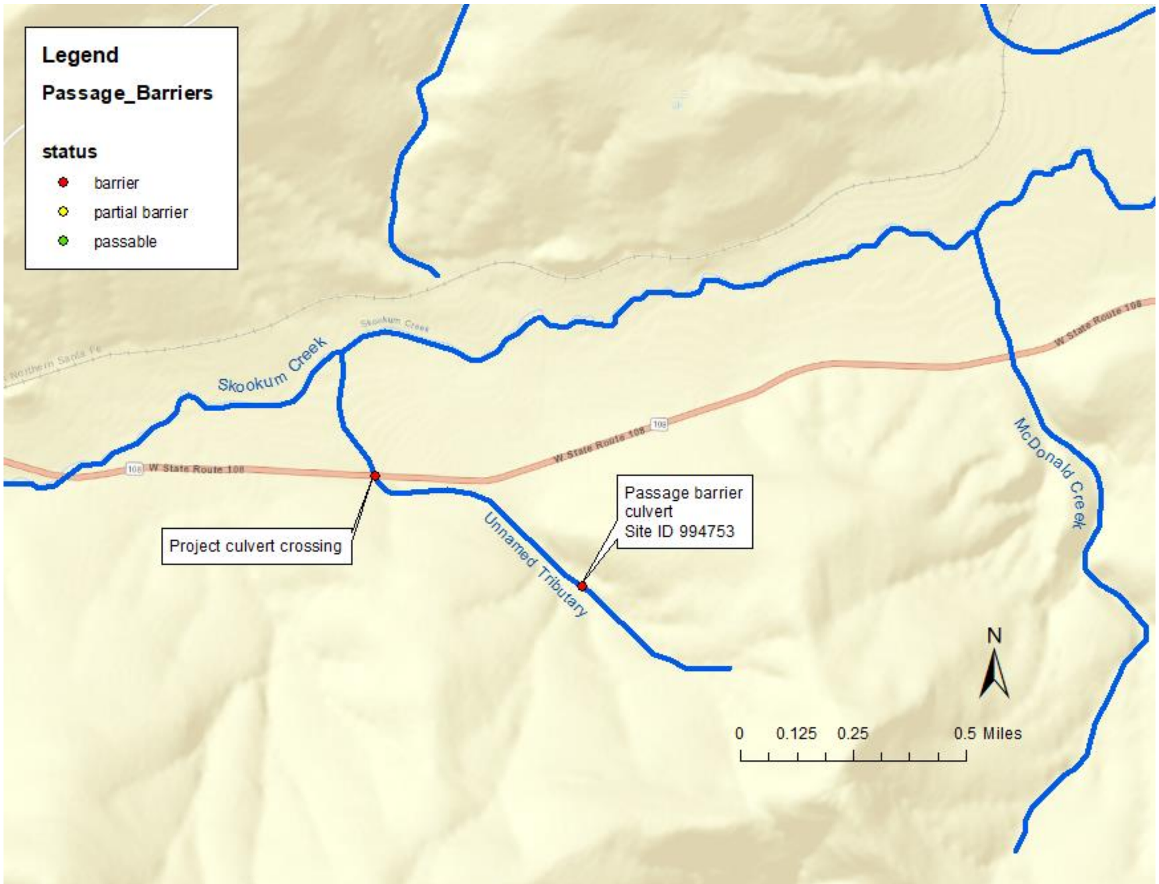


Figure 17 Fish passage features located on the Unnamed Tributary

5.0 Reference Reach Selection

The stream reach upstream of the existing SR 108 crossing was determined to be more representative of the natural channel than the downstream reach. A reference reach was identified approximately 250 feet upstream of the existing culvert inlet, between bankfull width measurements 1 and 2. The reach downstream of the existing SR 108 crossing is deeply incised with significant bank erosion and is therefore not representative of the natural channel at the existing culvert.

Two bankfull width measurements were taken approximately 300 feet and 200 feet upstream of the existing culvert inlet, which measured 14 feet and 14.6 feet respectively. For comparison, a bankfull width was calculated based on the WDFW regression equation for high-gradient, coarse-bedded streams in western Washington, using the basin area (0.61 square miles) and average mean annual precipitation (79.0 inches/year). The calculated bankfull width of 11.0 feet is 21-25% smaller than the field-measured bankfull widths. During the stakeholder site visit with WDFW, it was agreed upon to average the two bankfull widths for a design bankfull width of 14.3 feet.

A pebble count was performed at the reference reach approximately 250 feet upstream of the existing culvert inlet. The results of the pebble count are discussed in Section 3.4.6. Figure 18 shows the approximate BFW measurement and pebble count locations.

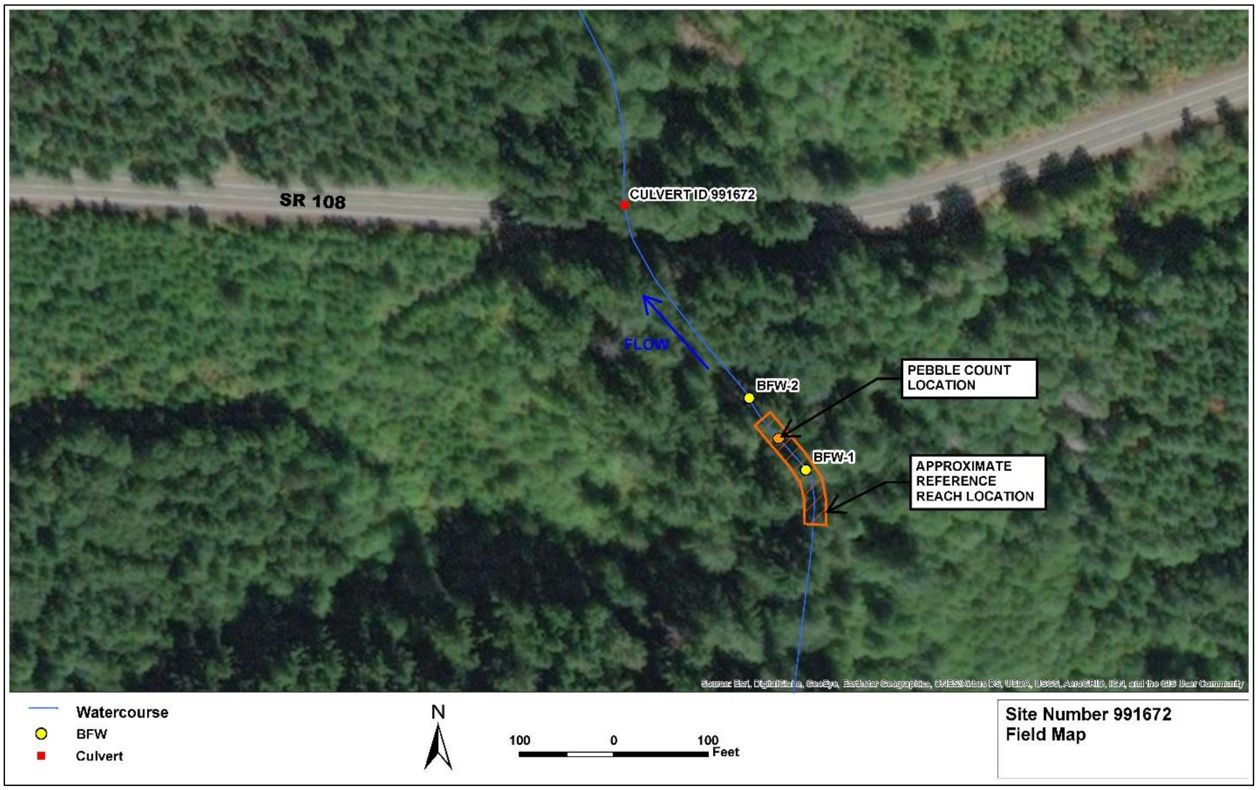


Figure 18 Bankfull width and pebble count measurement locations

6.0 Hydrology and Peak Flow Estimates

Due to lack of stream flow data on the Unnamed Tributary, peak flow estimates for the Unnamed Tributary were obtained from the USGS Regression Equation (Mastin, et al., 2016). The Unnamed Tributary has a basin area of 0.61 square miles and a mean annual precipitation within the basin of 79.0 inches (PRISM, 2019). Table 3 shows the calculated peak flows and prediction intervals (at a 90% confidence level) for the Unnamed Tributary at SR 108.

Table 3 Peak flows, Standard Error of Prediction and Prediction Intervals (at a 90% confidence interval) for the Unnamed Tributary at SR 108

Mean Recurrence Interval (MRI)	Unnamed Tributary (cfs)	Standard Error of Prediction	Prediction Interval (lower)	Prediction Interval (upper)
2	39.5	43.2	19.9	78.5
5	61.1	44.4	30.1	124
10	75.3	45.6	36.6	155
25	93.1	48.1	43.4	200
50	106	50.5	48.0	234
100	120	51.8	53.2	271
200	133	54.2	56.8	311
500	152	57.7	62.1	372

7.0 Hydraulic Analysis

The hydraulic analysis of the existing and proposed SR 108 Unnamed Tributary crossing was performed using Bureau of Reclamation’s SRH-2D Version 3.2.0 (USBR, 2017) computer program, a two-dimensional hydraulic and sediment transport model. It includes the ability to model dynamic interactions between the stream channel and overbanks, roadway overtopping, culverts, and the influence of bridge decks on bridge backwater. Pre- and post-processing of the model was completed using SMS Version 13.0.5 (Aquaveo, 2018). Appendix A contains detailed output from the hydraulic modeling effort.

Two scenarios were analyzed for determining stream characteristics for the Unnamed Tributary with the SRH-2D models: 1) existing conditions with the circular, corrugated steel, 5 foot diameter culvert and 2) future conditions with the proposed bridge with a 28 foot minimum hydraulic opening.

7.1 Model Development

7.1.1 Topography

Detailed channel geometry data in the model was obtained from the MicroStation and InRoads files, which were developed from topographic surveys performed by Lin & Associate surveyors. Proposed channel geometry was developed form the proposed grading surface created by HDR Engineering, Inc.

7.1.2 Model Extent and Computational Mesh

The hydraulic model upstream and downstream extents are consistent with the detailed survey boundary, approximately 320 feet upstream of the existing culvert outlet and 310 feet downstream of the existing culvert outlet, measured along the channel centerline. The computational mesh elements was a combination of patched and paved (triangular) elements, with finer resolution in the channel and larger elements in the floodplain (Figure 19).

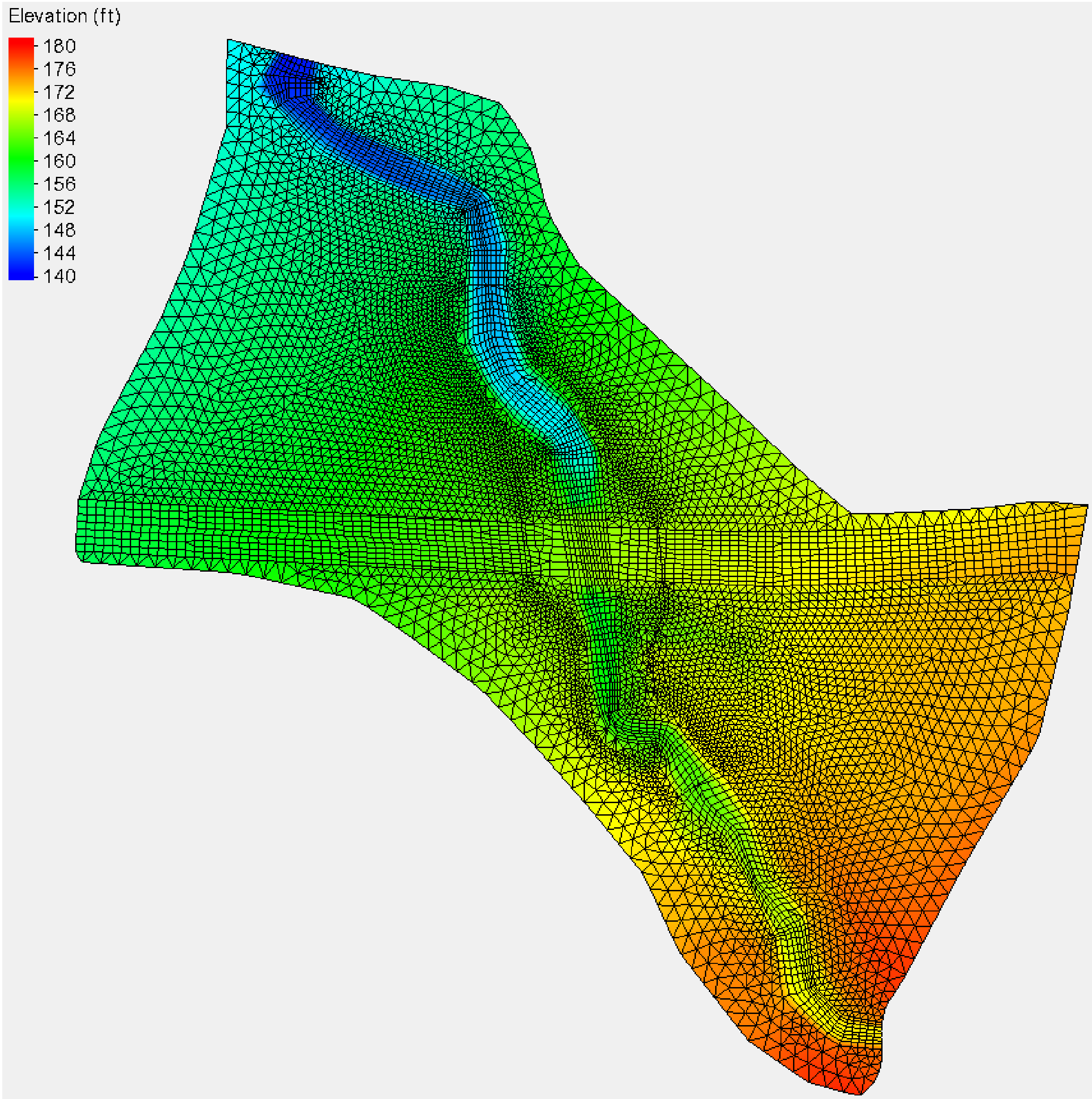


Figure 19 Existing computational mesh with underlying terrain

7.1.3 Roughness

Manning's n values were estimated based of site observations, aerial photography and standard engineering values (Chow, 1959) and are summarized below (Table 4). The downstream channel roughness was modeled slightly higher than the upstream channel to represent the additional debris and obstructions within the existing channel. Roughness in the overbanks represents dense vegetation and undergrowth associated with the grasses, shrubs and trees in the riparian areas.

Table 4 Summary of roughness coefficients

Land Cover	Manning's Roughness Coefficient
Channel	Upstream - 0.06 Downstream – 0.047
Road	0.02
Floodplain	0.12

7.1.4 Boundary Conditions

Model simulations were performed using multiple quasi-steady state discharges ranging from the 2-year to 500-year peak flow events summarized described in Chapter 6. External boundary conditions were applied at the upstream and downstream extents of the model and remained the same between the existing and proposed conditions runs. A constant flow rate was specified at the upstream external boundary condition, while a normal depth rating curve was specified at the downstream boundary. The downstream normal depth boundary condition rating curve was developed within SMS using the existing terrain, assuming a downstream slope of 4% as measured form the survey and a composite roughness of 0.047.

A HY-8 internal boundary condition was specified in the existing conditions model to represent the existing pipe arch crossing. The existing crossing was modeled as a 5 foot diameter circular pipe within HY-8. A manning's roughness of 0.024 was assigned to the culvert. The culvert was assumed to be unobstructed and free from any stream material within the barrel.

7.1.5 Model Geometries

Two geometries were developed for simulation with SRH-2D, representing existing and proposed conditions. The existing conditions includes the existing circular culvert crossing of SR 108. The existing condition geometry was modified to develop the proposed conditions by removing the existing culvert and associated internal boundary conditions. Additionally the terrain was updated to reflect the proposed grading and 20-foot span hydraulic opening. The walls of the proposed structure were modeled as voids in the computational mesh. Model geometry outside of the proposed improvements are the same for the proposed conditions as the existing condition.

7.2 Model Results

Hydraulic results were summarized and compared at common locations between the existing and proposed simulations (Figure 20). The upstream cross section is located at approximate station 4+09 and is 25 feet upstream of the existing culvert inlet. Downstream the cross section was located at station 2+17, 115 feet downstream of the existing culvert outlet. Hydraulic variables reported include water surface elevation, depth, velocity and shear stress. Appendix A contains the more detailed hydraulic output.

In addition to cross section results, results were summarized along the longitudinal profile. Both existing and proposed conditions use the same alignment (Figure 21).

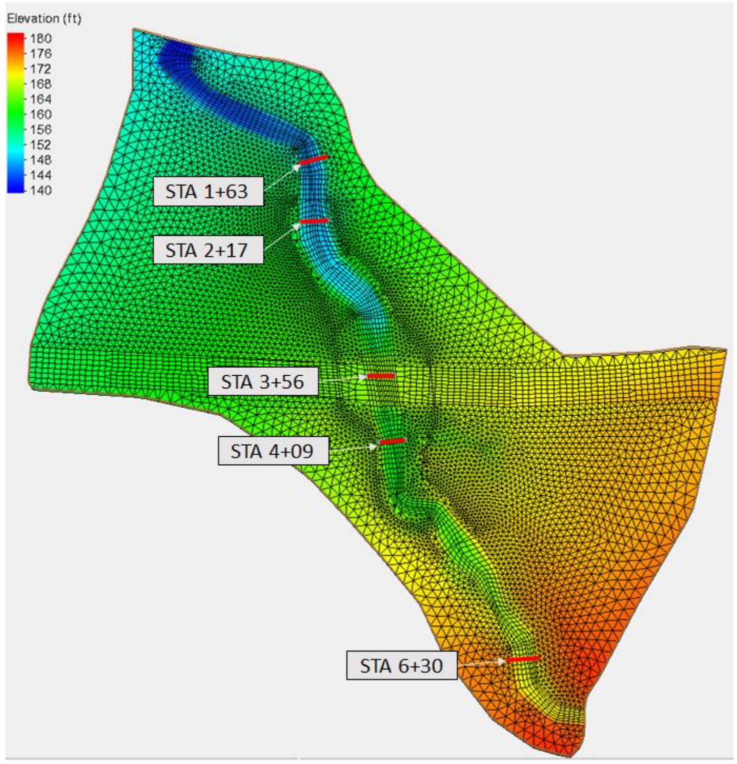


Figure 20 Locations of cross sections used for results reporting

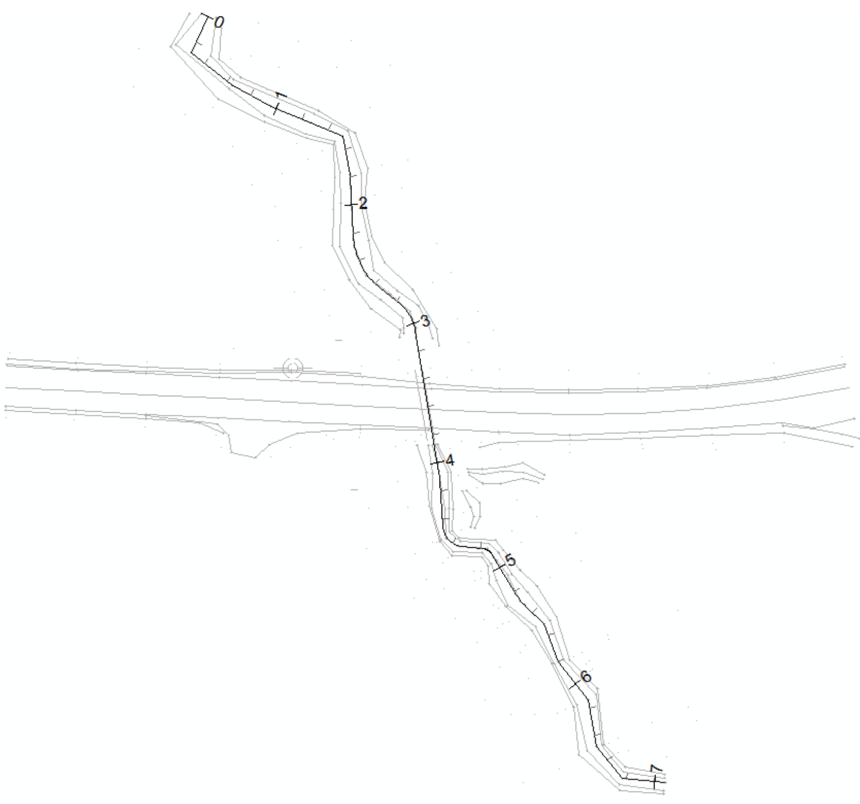


Figure 21 Longitudinal profile stationing for existing and proposed conditions

7.2.1 Existing conditions – 5 foot, circular CMP

Existing conditions hydraulic results are summarized for the upstream and downstream cross sections in Table 5 below. Under existing conditions, the culvert causes a backwater upstream for the range of flows simulated (Figure 22). Pressure flow conditions were not observed during any of the flow events.

As a result of the backwater, the upstream depths are greater than the downstream reach. In addition, the upstream shear and velocities are lower than their downstream counter parts. Upstream cross section velocities varied from 2.24 ft/sec during the 2-year event to 6.76 ft/sec during the 500-year event. At the downstream cross sections velocities ranged from 3.71 ft/sec at the 2-year event to 4.78 ft/sec at the 25-year event. Shear varied from 0.31 lb/ft^2 to 3.18 lb/ft^{2}at the upstream cross sections during the 500-year event. Shear values present in the downstream cross sections, ranging from 0.97 lb/ft^{2}during the 2-year event to 2.01 lb/ft^2 at the 500-year event. When looking at the entire model domain, the largest velocities occurred at the culvert outlet (Figure 23).

Table 5 Hydraulic results for existing conditions within channel

Hydraulic Parameter	Cross Section	2-yr	25-yr	50-yr	100-yr	500-yr
Average Water Surface Elevation (ft)	XS 1+63	147.62	148.04	148.18	148.31	148.80
	XS 2+17	148.53	148.90	149.07	149.21	149.72
	XS 4+09	161.03	161.98	162.37	162.80	163.77
	XS 6+30	169.38	169.89	170.00	170.10	170.10
Max Depth (ft)	XS 1+63	1.39	1.80	1.94	2.08	2.55
	XS 2+17	1.27	1.63	1.79	1.93	2.45
	XS 4+09	1.80	2.76	3.14	3.56	4.53
	XS 6+30	0.97	1.46	1.57	1.68	1.66
Average Velocity (ft/s)	XS 1+63	3.75	4.09	4.29	4.53	4.56
	XS 2+17	4.03	4.78	4.18	3.94	3.71
	XS 4+09	2.24	2.58	2.49	2.40	2.34
	XS 6+30	3.60	5.18	5.08	5.35	6.76
Average Shear (lb/sq-ft))	XS 1+63	0.97	1.19	1.28	1.37	2.01
	XS 2+17	1.10	1.36	1.16	1.11	1.45
	XS 4+09	0.53	0.72	0.63	0.56	0.31
	XS 6+30	1.85	3.04	3.04	3.25	3.18

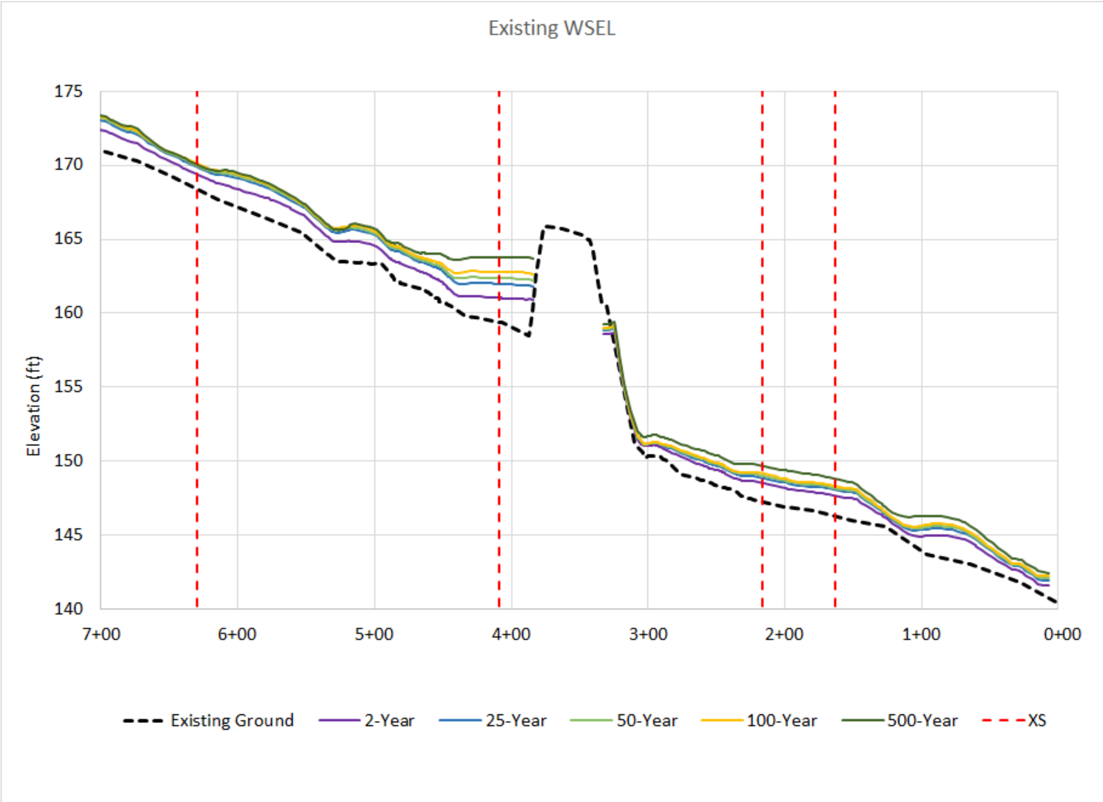


Figure 22 Existing conditions water surface profiles

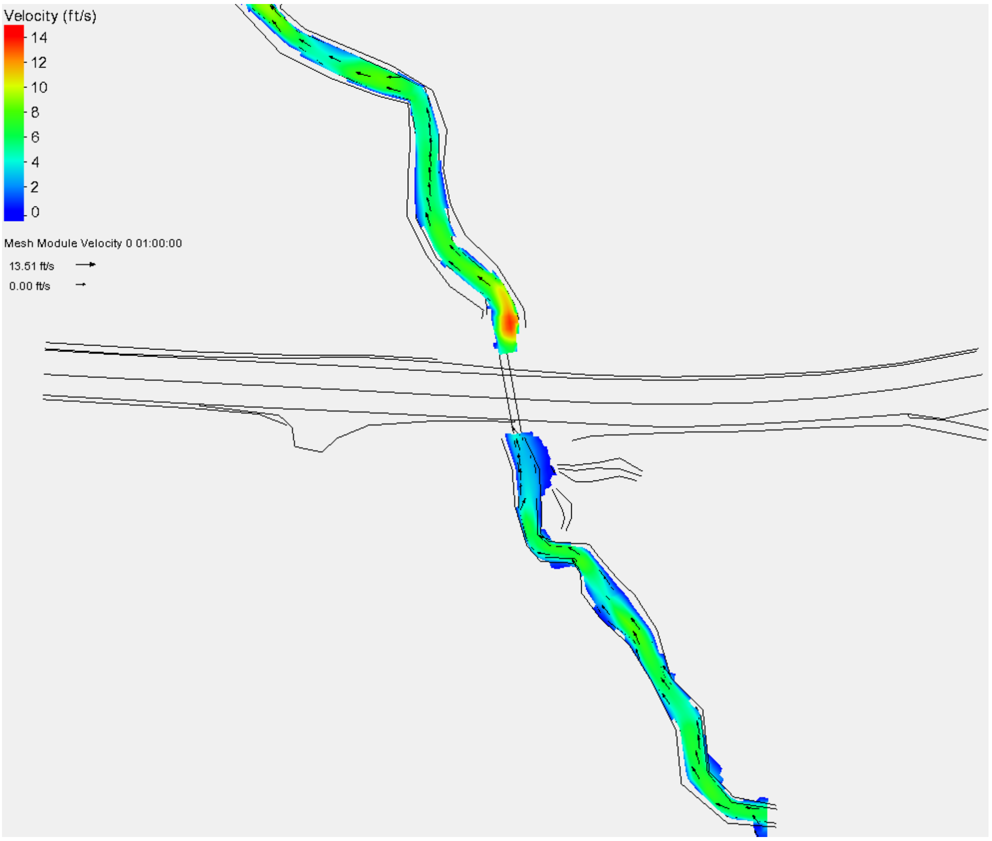


Figure 23 Existing conditions 100-year velocity map

7.2.2 Future conditions – Proposed 28 Foot Span Structure

Proposed conditions hydraulic results are summarized for the upstream and downstream cross sections in Table 6. The larger proposed structure does not cause any backwater (Figure 24). The 100-year water surface elevation upstream of the crossing was decreased by 2.02 ft when compared to existing conditions.

With the removal of the backwater condition, upstream channel velocities generally increased from existing conditions. Velocities at upstream cross sections vary from 3.6 ft/sec during the 2-year event to 6.11 ft/sec during the 500-year event. At downstream cross sections velocities vary from 3.23 to 5.79 ft/sec. Similar to the velocity results, shear generally increased upstream of the crossing, varying from 2.04 to 4.01 lb/ft^2. At the downstream cross section, shear values also increased from existing conditions varying at upstream cross sections from 1.85 lb/ft^2 to 4.01 lb/ft^2. The hydraulics within the proposed crossing indicate this reach is a transition from the reach upstream of the crossing to the downstream reach. Velocities, depths, and shear within the proposed crossing are all between the results of the upstream and downstream cross section. When looking at the entire model domain, proposed velocities upstream of the crossing increased compared to existing conditions. The velocity at the outlet of the crossing into the existing scour hole is decreased (Figure 25).

Table 6 Hydraulic results for proposed conditions within channel

Hydraulic Parameter	Cross Section	2-yr	25-yr	50-yr	100-yr	500-yr
Average Water Surface Elevation (ft)	XS 1+63	147.35	148.04	148.18	148.31	148.62
	XS 2+17	148.73	149.21	149.30	149.40	149.60
	XS 3+56	155.95	156.41	156.51	156.60	156.79
	XS 4+09	158.72	159.18	159.28	159.37	159.56
	XS 6+30	169.38	169.89	170.00	170.10	170.33
Max Depth (ft)	XS 1+63	1.11	1.80	1.94	2.08	2.38
	XS 2+17	0.90	1.38	1.47	1.57	1.77
	XS 3+56	0.89	1.35	1.45	1.54	1.73
	XS 4+09	0.88	1.34	1.44	1.54	1.72
	XS 6+30	0.97	1.46	1.57	1.68	1.91
Average Velocity (ft/s)	XS 1+63	3.23	4.09	4.30	4.54	4.94
	XS 2+17	4.13	4.73	5.01	5.27	5.79
	XS 3+56	3.80	5.61	5.18	5.50	6.10
	XS 4+09	3.82	5.62	5.19	5.51	6.11
	XS 6+30	3.60	5.18	5.08	5.35	5.87
Average Shear (lb/sq-ft))	XS 1+63	0.79	1.18	1.28	1.37	1.52
	XS 2+17	2.18	2.85	3.09	3.34	3.84
	XS 3+56	2.00	3.45	3.12	3.41	4.00
	XS 4+09	2.04	3.49	3.14	3.43	4.01
	XS 6+30	1.85	3.04	3.04	3.25	3.63

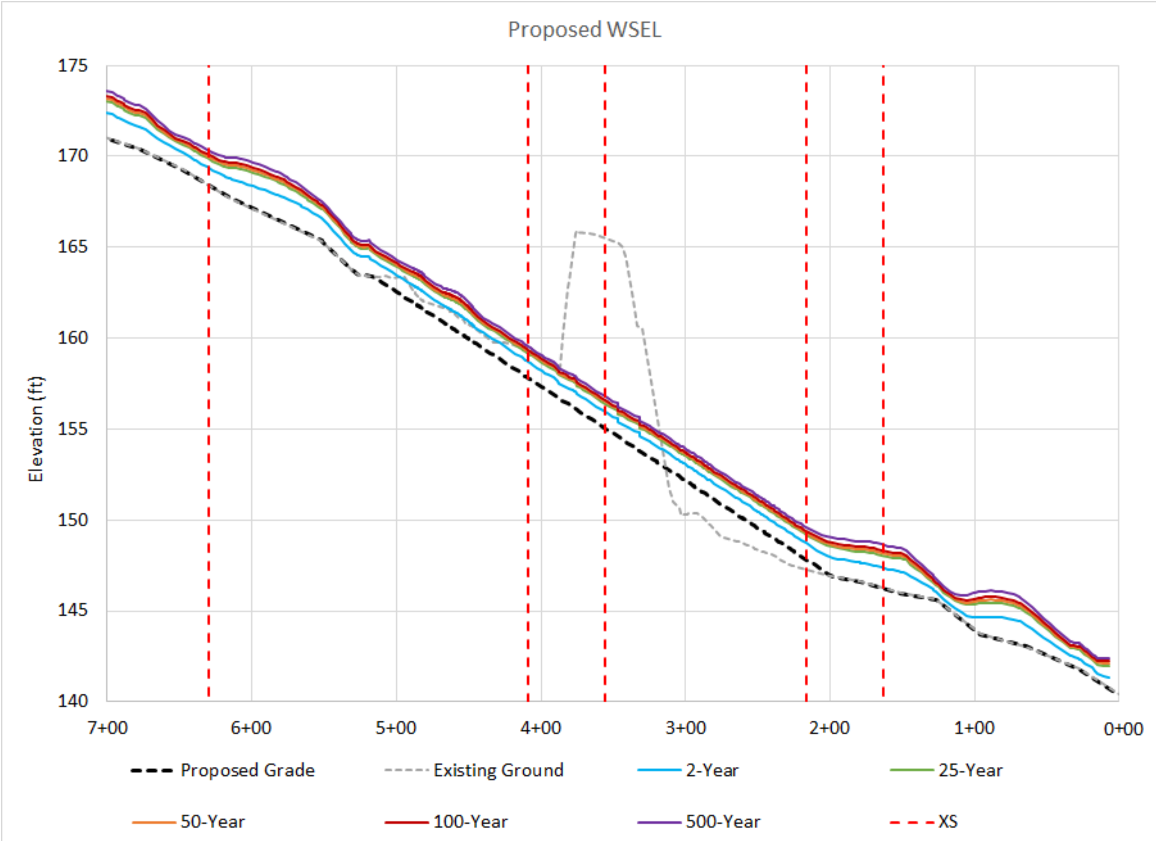


Figure 24 Proposed conditions water surface profiles

Figure 25 Proposed conditions 100-year velocity map

8.0 Fish Passage Design Methods Selection

8.1 Design Methodology Selection

The WCDG contains methodology for five different types of crossings: No-Slope Culverts, Stream Simulation Culverts, Bridges, Temporary Culverts or Bridges, and Hydraulic Design Fishways. The permanent federal injunction allows for the use of the stream simulation method and bridge design method unless extraordinary circumstances exist on site. According to the WCDG, a bridge should be considered for a site if the Floodplain Utilization Ratio (FUR) is greater than 3.0, the stream has a bankfull width of greater than 15 feet, the channel is believed to be unstable, the slope ratio exceeds 1.25 between the existing channel and the new channel, or the culvert would be very long. Using these design criteria, bridge criteria was deemed the most appropriate method for this crossing because the channel appears to be unstable with a steep gradient and a large headcut directly downstream of the project.

8.2 Bridge Design Criteria

The 2013 WDFW Water Crossing Design Guidelines (WCDG) present two methodologies for designing a bridge crossing—confined bridge design and unconfined bridge design. The method to be used is defined by the Floodplain Utilization Ratio (FUR). The FUR is defined as the flood-prone width (FPW) divided by the bankfull width. The FPW is the water surface width at twice the bankfull depth, or the width at the 50-year to 100-year flood. A ratio under 3.0 is considered a confined channel and above 3.0 is considered an unconfined channel.

The downstream channel is highly incised and has a FUR equal to 1. The upstream reach 100-year FPW is varies from approximately 16 feet to 21 feet, resulting in a FUR of 1.1 to 1.5.

8.2.1 Confined Bridge Design Width Criteria

The proposed crossing is a confined channel. The proposed structure size will follow the WCDG recommendation of span based on the agreed upon bankfull width. With the span being 1.2 x bankfull width + 2 feet (WCDG Equation 3.2) plus a factor of safety. Using this equation, along with the measured bankfull width of 14.3 feet discussed in Section 5.0, results in a structure span of 19.2 feet. This was rounded up to the nearest whole foot of 20 feet.

A factor of safety was apply to the crossing to increase the minimum structure size to 28 feet to accommodate the potential for a downstream headcut to propagate through the site. The top width of the incised downstream channel ranges from approximately 20 feet to 28 feet. Therefore, increasing the structure size to 28 feet was deemed appropriate to accommodate potential channel changes propagating from downstream of the project through the proposed crossing.

8.2.2 Backwater and Freeboard

The WCDG recommends the prevention of excessive backwater rise and increased main channel velocities during floods that might lead to scour of the streambed and coarsening of the stream substrate, allow the free passage of debris expected to be encountered, and generally suggests a minimum 2 foot freeboard for streams of this size. The minimum freeboard at this site was increased to 3.0 feet to accommodate potential debris and sediment aggradation in this highly energetic system. It is practicable to meet the minimum 3 feet of freeboard at this crossing.

An additional recommendation is to provide a minimum of 5 feet clearance above the channel thalweg if practicable to perform future maintenance, allowing for wildlife to cross, and performing monitoring activity. The 100-year water surface depth is approximately 1.53 feet at the upstream bridge face. Therefore, the low chord elevation based on freeboard recommendations would be 4.53 feet above the thalweg. The recommended low chord elevation was raised to meet the 5-foot minimum recommendation to an elevation of 161.7 feet.

8.2.3 Channel Planform and Shape

The WCDG requires that the channel planform and shape mimic conditions within a reference reach. The proposed channel shape includes 20H:1V slopes between the toes and 2H:1V bank slopes above the toe. The typical channel section is illustrated in Figure 26.

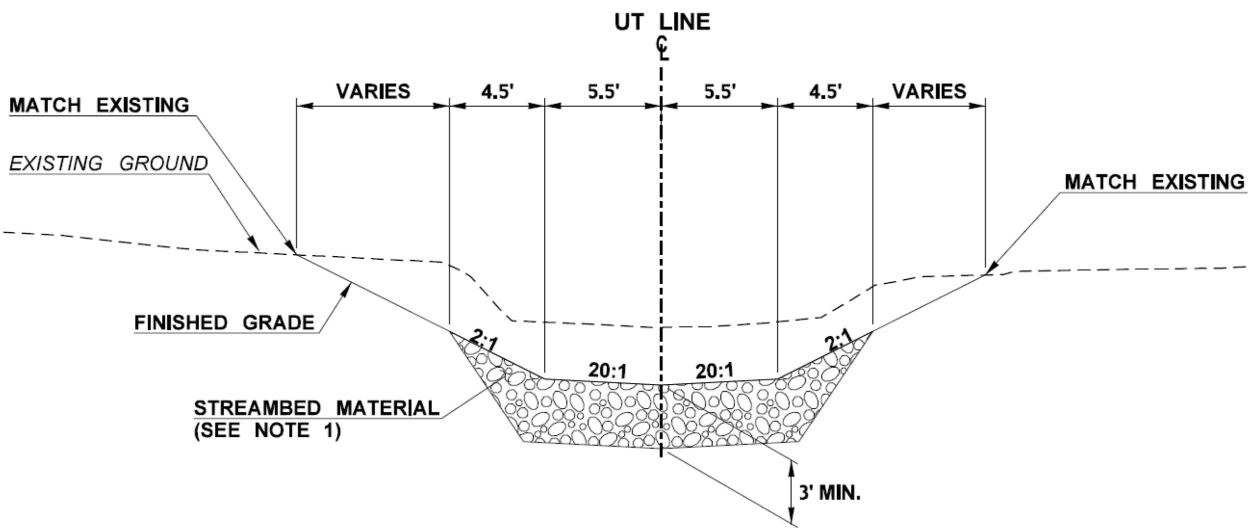


Figure 26 Typical channel section (looking upstream)

8.2.4 Floodplain Continuity and Lateral Migration through Structure

The WCDG requires that bridges account for lateral channel movement that will occur in their design life and that the design channel maintains floodplain continuity. The existing channel upstream and downstream are highly confined and have nearly no access to its overbank floodplains. Most of the migration appears to be localized bank erosion.

8.2.5 Channel Gradient

The WCDG recommends that the proposed culvert bed gradient not be more than 25% steeper than the existing stream gradient upstream of the crossing (WCDG Equation 3.1). The proposed channel gradient 5.2% and the existing upstream average gradient is approximately 4.3%, resulting slope ratio of 1.2.

9.0 Streambed Design

9.1 Alignment

The proposed project alignment closely follows the existing alignment. Channel grading will extend approximately 130 feet downstream of the existing culvert outlet and 130 feet upstream of the existing culvert inlet.

9.2 Proposed Section

Description of the existing and proposed cross section are presented in Section 8.2.3. A low flow channel will be added in later stages of the project that connect habitat features together and ensure the project is not a low flow barrier. The low flow channel will be as directed by the Engineer in the field.

9.3 Bed Material

The proposed bed material gradation was created using standard WSDOT specification material to mimic the gradation documented in the pebble count as best possible. The proposed mix will consists of one part Streambed Sediment, one part 4-inch Streambed Cobbles, and one part 8-inch Streambed Cobbles. A comparison of the observed and proposed streambed material size distribution is provided in Table 7. The Unnamed Tributary appeared to have an active bed with high energy. Therefore it was deemed most appropriate to match the existing material that is anticipated to be delivered from the upstream reach.

Table 7 Comparison of observed and proposed streambed material

Particle	Observed Material Diameter (in)	Proposed Material Diameter (in)
D_{15}	0.6	0.4
D_{50}	2.1	1.9
D_{84}	4.2	3.9
D_{95}	5.8	6.8
D_{100}	10.1	8.0

9.4 Channel Habitat Features

Large Woody Material will be installed in portions of the Unnamed Tributary. These LWM installations will provide structures conducive to create stream complexity and geomorphic functions in segments that will have low natural LWM delivery rates while new and impacted riparian areas recover from construction activities related to the installation of the new crossing and the regrading of the stream channels. LWM, in conjunction with habitat boulders and bank-side bioengineering, will also help protect newly constructed banks and will promote long-term stability by creating pools, sinuosity, hard points, and channel roughness.

9.4.1 Design Concept

The 75th percentile of key piece density per Fox and Bolton (2007) and Chapter 10 of the Hydraulics Manual recommend 3.3 key pieces per 100 feet of channel. This percentile of wood placement is suggested to compensate for cumulative deficits of wood loading due to development. A conceptual LWM layout has been developed for the Unnamed Tributary project area and is provided in Figure 27. The conceptual layout proposes 19 key pieces. The project reach is approximately 318 feet long (including the structure), yielding 6.0 key pieces per 100 feet of linear channel, 82% more than the Fox and Bolton (2007) 75th percentile criteria to account for portions of the channel where infrastructure limits LWM placement. The conceptual layout also includes boulder clusters under the structure to provide stream complexity under the structure.

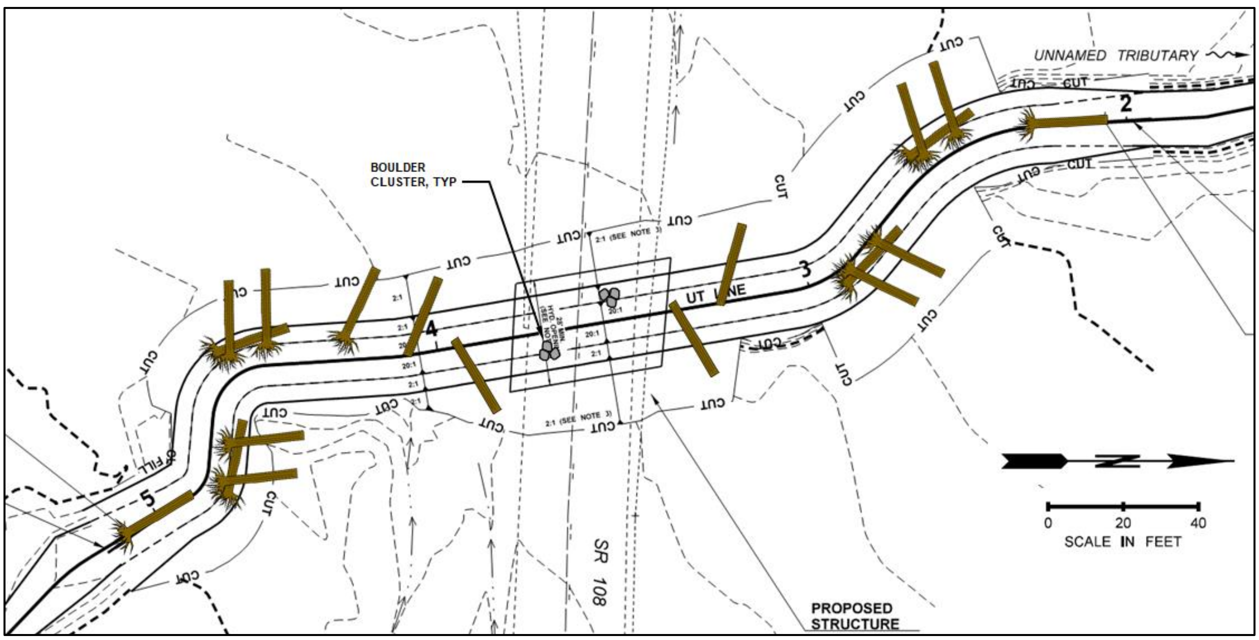


Figure 27 Proposed grading and conceptual wood layout

10.0 Floodplain Changes

This project is not within a FEMA mapped floodplain.

10.1 Floodplain Storage

Floodplain storage is anticipated to be nearly unaffected. There is some fill within the channel downstream of the crossings but also removal of the undersized culvert and replacement with a larger hydraulic opening. The installation of a larger hydraulic opening reduces the amount of backwater being stored upstream of the crossing and reduces any peak flow attenuation that was being provided by the smaller, existing culvert. Changes to peak flow reduction was not quantified as the models were run in a quasi-steady state flow with a constant flow rate specified at the upstream boundary of the model.

10.2 Water Surface Elevations

Installation of the proposed structure will eliminate the backwater impacts upstream of the existing culvert, resulting in a reduction in water surface elevation. Preliminary hydraulic results indicate that there is a reduction in water surface elevation of 3.43 and 4.21 feet during the 100 and 500-year events at the upstream cross section, respectively. Just downstream of the culvert, the proposed grading results in a large amount of fill, so the water surface elevations showed a max increase of 3 feet during the 100 year event.

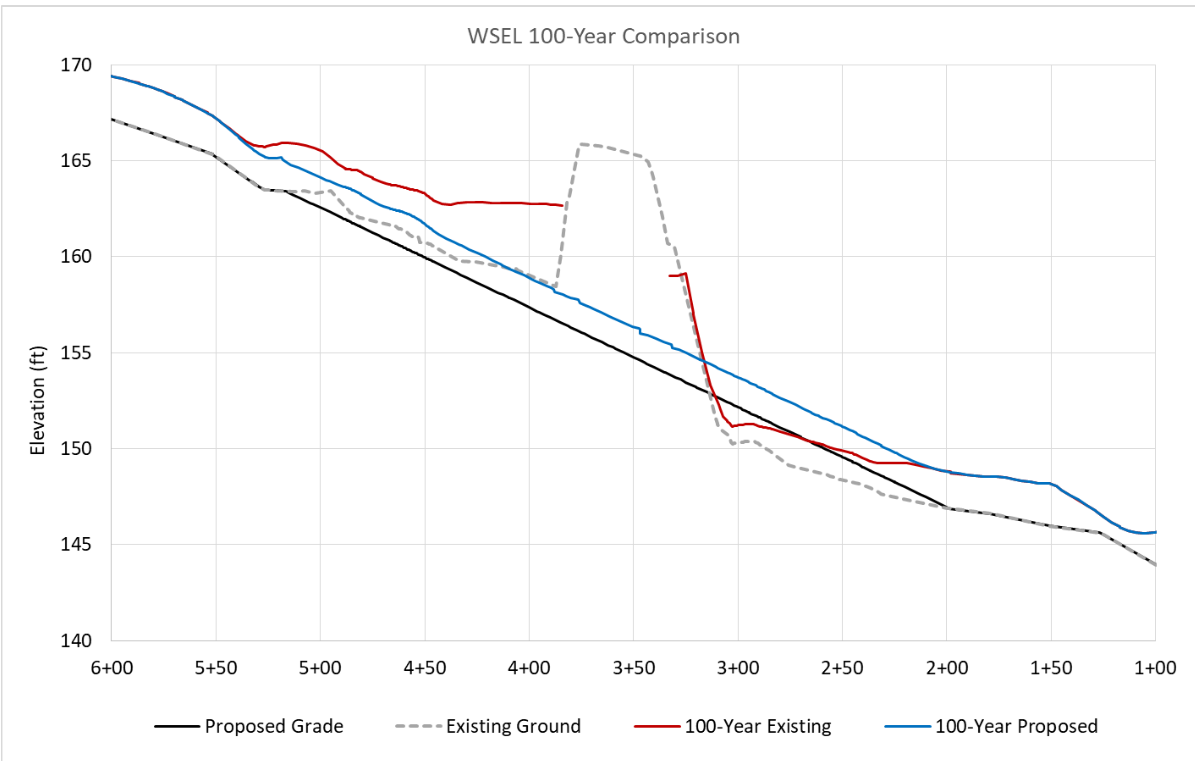


Figure 28 Existing and proposed 100-Year water surface profile comparison

Figure 28 provides a comparison of the existing and proposed 100-year water surface profile. The hydraulic simulations indicate an increase in water surface elevations downstream of the proposed crossing with a maximum increase of approximately 3 feet. The increase in water surface can be attributed to the grading changes. While the water surface is increased downstream of the crossing it is still contained with the incised banks. Increases in the 100-year water surface are illustrated in Figure 29.

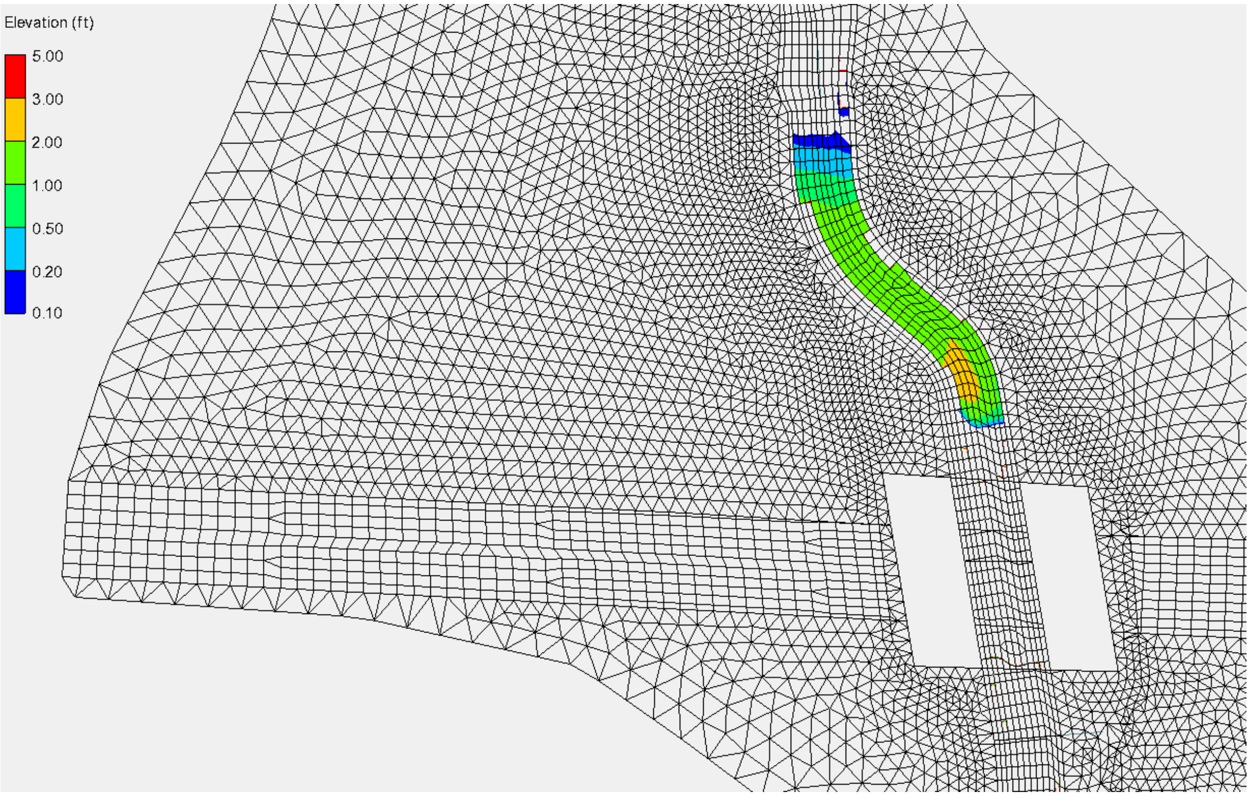


Figure 29 Areas of water surface elevation increase for the 100-year water surface

11.0 Climate Resilience

WSDOT recognizes climate resilience as a component of the integrity of its structures and approaches the design of bridges, and buried structures through a risk based assessment beyond the design criteria. For bridges and buried structures, the largest risk to the structures will come from increases in flow and/or sea level rise. The goal of fish passage projects is to maintain natural channel processes through the life of the structure and maintain passability for all expected life stages and species in a system.

11.1 Climate Resilience Tools

Climate resilience is evaluated at each crossing using the Climate Impacts Vulnerability Assessment Maps created by WSDOT to assess risk level of infrastructure across the state. The Unnamed Tributary at SR 108 crossing has been evaluated and determined to be a low risk site based on the Climate Impacts Vulnerability Assessment Maps.

WSDOT also evaluates crossings using the mean percent change in 100-year flood flows from the WDFW Future Projections for Climate-Adapted Culvert Design program. For low or medium risk sites, the 2040 percent increase is used. For high risk sites the 2080 percent increase is used. Appendix C contains the information received from WDFW for this site. The 100-year flow event was chosen to be evaluated, because, as it is an extreme event, if the channel behaves similarly through the structure during this event as it does the adjacent reaches, then it is anticipated this relationship would also be true at lower flows as well.

11.2 Hydrology

For each design WSDOT uses, the best available science for assessing site hydrology. The predicted flows are analyzed in the hydraulic model and compared to field and survey indicators, maintenance history, and any other available information. Hydraulic engineering judgment is used to compare model results to system characteristics; if there is significant variation, then the hydrology is re-evaluated to determine whether or not adjustments need to be made, including adding standard error to the regression equation, basin changes in size or use, etc.

In addition to using the best available science for current site hydrology, WSDOT is evaluating the structure at the 2040 projected 100-year flow event to check for climate resiliency. The Design Flow for the crossing is 120 cfs at the 100-year storm event. The projected increase for the 2040 flow rate is 9.4%, yielding a projected 2040 flow rate of 131 cfs.

11.3 Structure Width

The minimum width for a crossing given by Equation 3.2 was 19.2 feet. The structure width was increased to 28 feet to accommodate the potential of a downstream headcut propagating through the site. This structure width was evaluated at the 100-year flow event and projected 2040 100-year flow event and determined to produce similar velocities through the structure and adjacent reaches. The velocity comparisons for these flow rates can be seen in Table 8 below.

Table 8 Velocity comparison for 28 foot structure

	100-Year Velocity (ft/s)	Projected 100-Year Velocity (ft/s)	Difference (ft/s)	Difference (%)
Upstream of Structure	5.27	5.46	0.19	3.48
Through Structure	5.50	5.72	0.22	4.00
Downstream of Structure	5.51	5.73	0.22	3.99
Velocity Ratio	1.04	1.05	-	-

Note: Velocity ratio calculated as Vstructure/Vupstream

11.4 Freeboard and Countersink

The minimum recommended freeboard at this location based on bankfull width was 2 feet at the 100-year flow event. The minimum freeboard was increased to 3 feet to accommodate potential debris and sediment aggradation in this highly energetic system. An additional consideration for maintenance, wildlife crossings, and monitoring activities increased the recommended low chord 0.47 feet above the 3 feet requirement to an elevation of 161.7 feet. The projected 2040 100-year flow event is anticipated to increase the 100-year water surface elevation by 0.07 feet to a water surface elevation of 158.36 feet.

Therefore, the previously proposed low chord elevation in Section 8.2.2 of 161.7 feet will provide more than 3 feet of freeboard during the projected 2040 100-year flow event.

Long term degradation and aggradation, contraction scour and local scour were not evaluated for this preliminary hydraulic design and will need to be evaluated during the final design, as discussed in Section 12. However, this stream is high gradient and appears to have the ability to move a lot of material and debris. It is recommended that a bottomless structure or bridge be considered during the next phase of design. A preliminary estimate of long term degradation was made by projecting the average downstream slope through the project reach, resulting in an approximate long term degradation depth of 2 to 3 feet below the proposed grade. Pending the outcome of the detailed scour analysis, the preliminary design and depth of countersink will be revised to account for the total potential scour associated with the projected 2040 100-year flow event.

11.5 Summary

A minimum hydraulic opening of 28 feet and minimum low chord elevation of 161.7 feet allows for the channel to behave similarly through the structure as it does in the adjacent reaches under the projected 2040 100-year flow event. This will provide a robust structure design that is resilient to climate change and allow the system to function naturally, including the passage of sediment, debris and water in the future.

12.0 Scour Analysis

Scour calculations were not performed during the preliminary design, but will be performed following the procedures outlined in *Evaluating Scour at Bridges HEC No. 18* (Arneson et al. 2012) during final design. Scour components to be considered in the analysis include:

1. Long-term aggradation/degradation
2. General scour (i.e., contraction scour)
3. Local scour

In addition to the three scour components above, potential lateral migration of a channel must be assessed when evaluating total scour at highway infrastructure.

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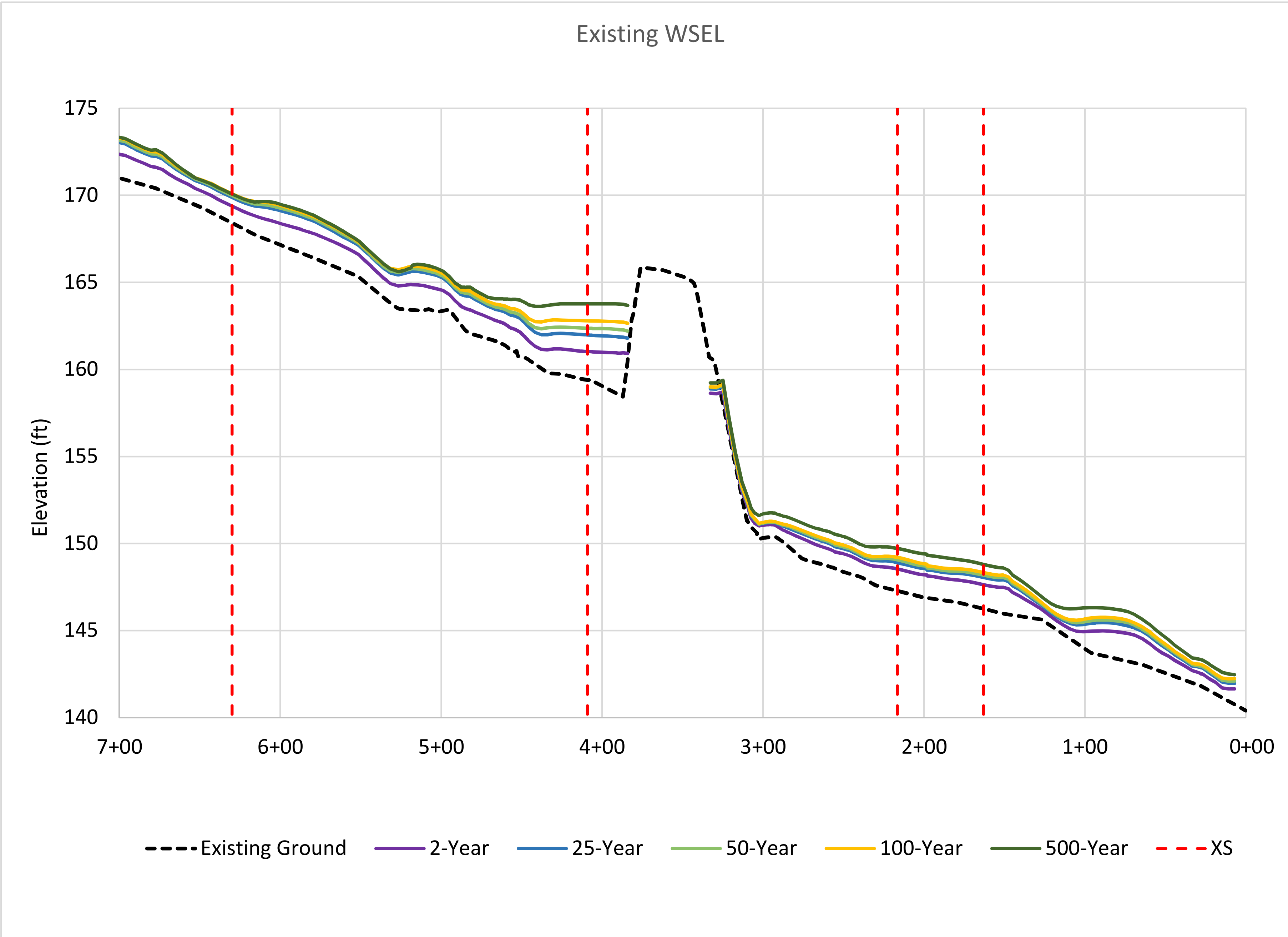
14.0 Appendices

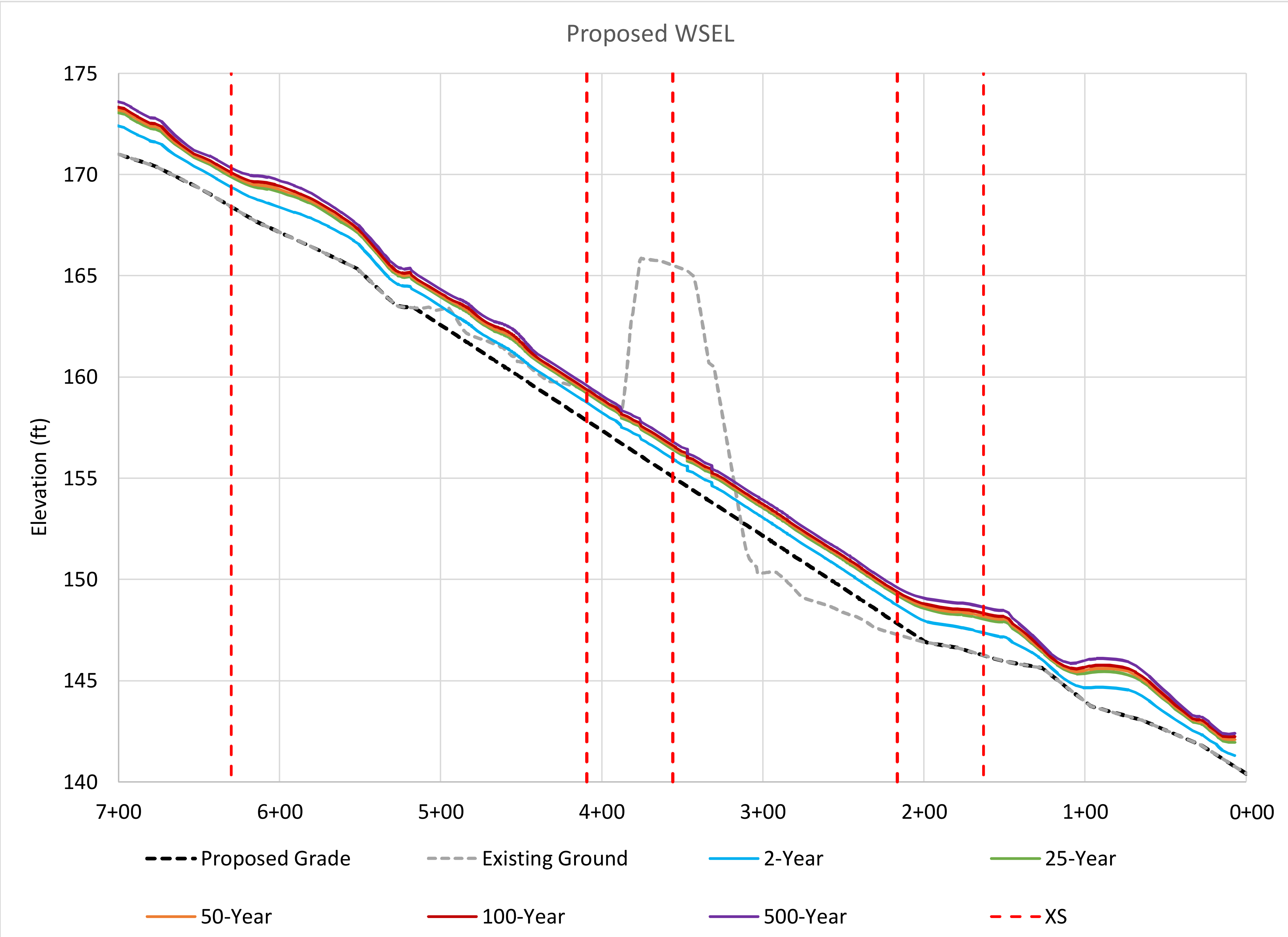
Appendix A – SRH-2D Model Results

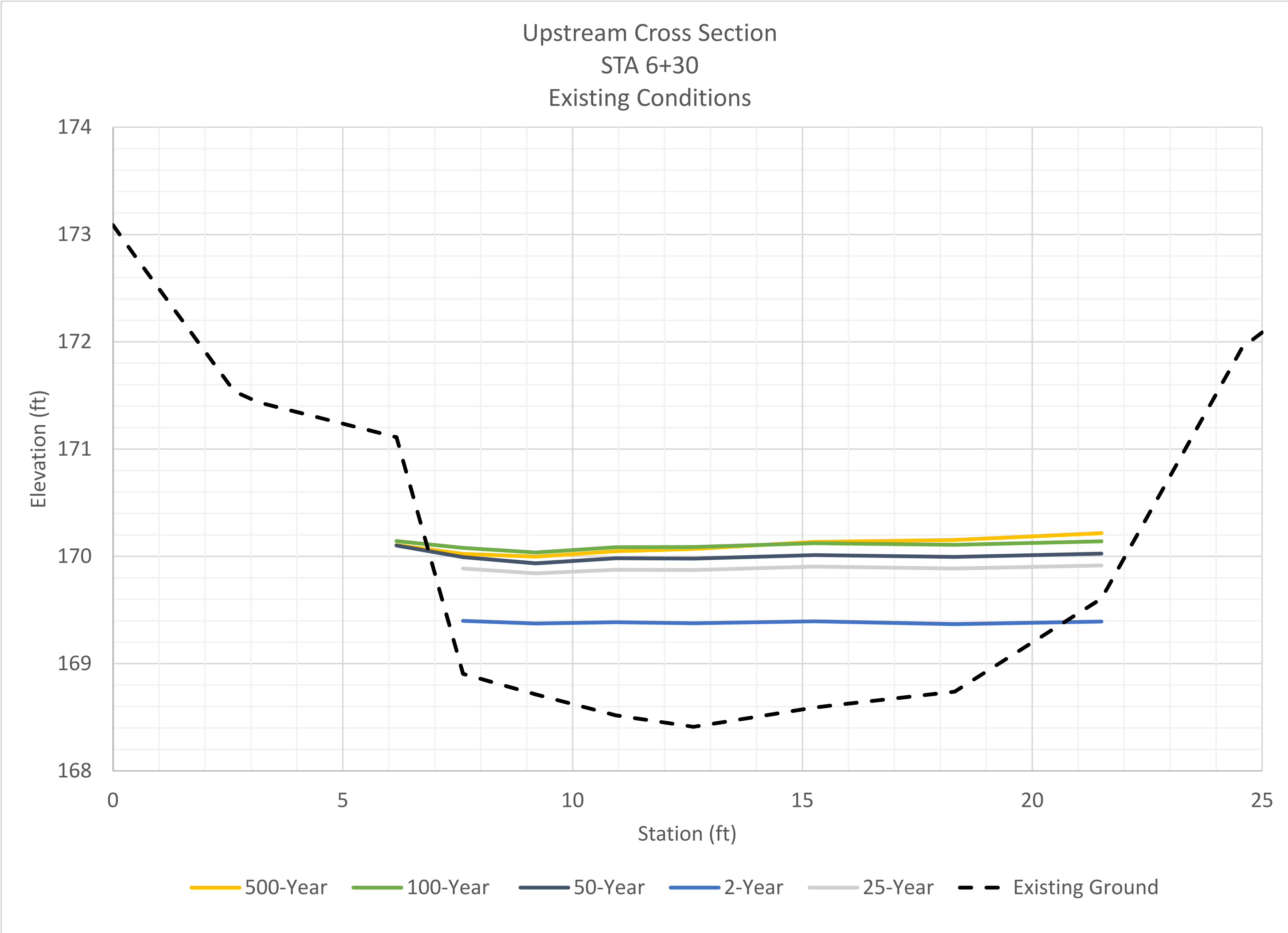
Appendix B – Stream Plan Sheets, Profile, Details

Appendix C – WDFW Future Projections for Climate-Adapted Culvert Design Printout

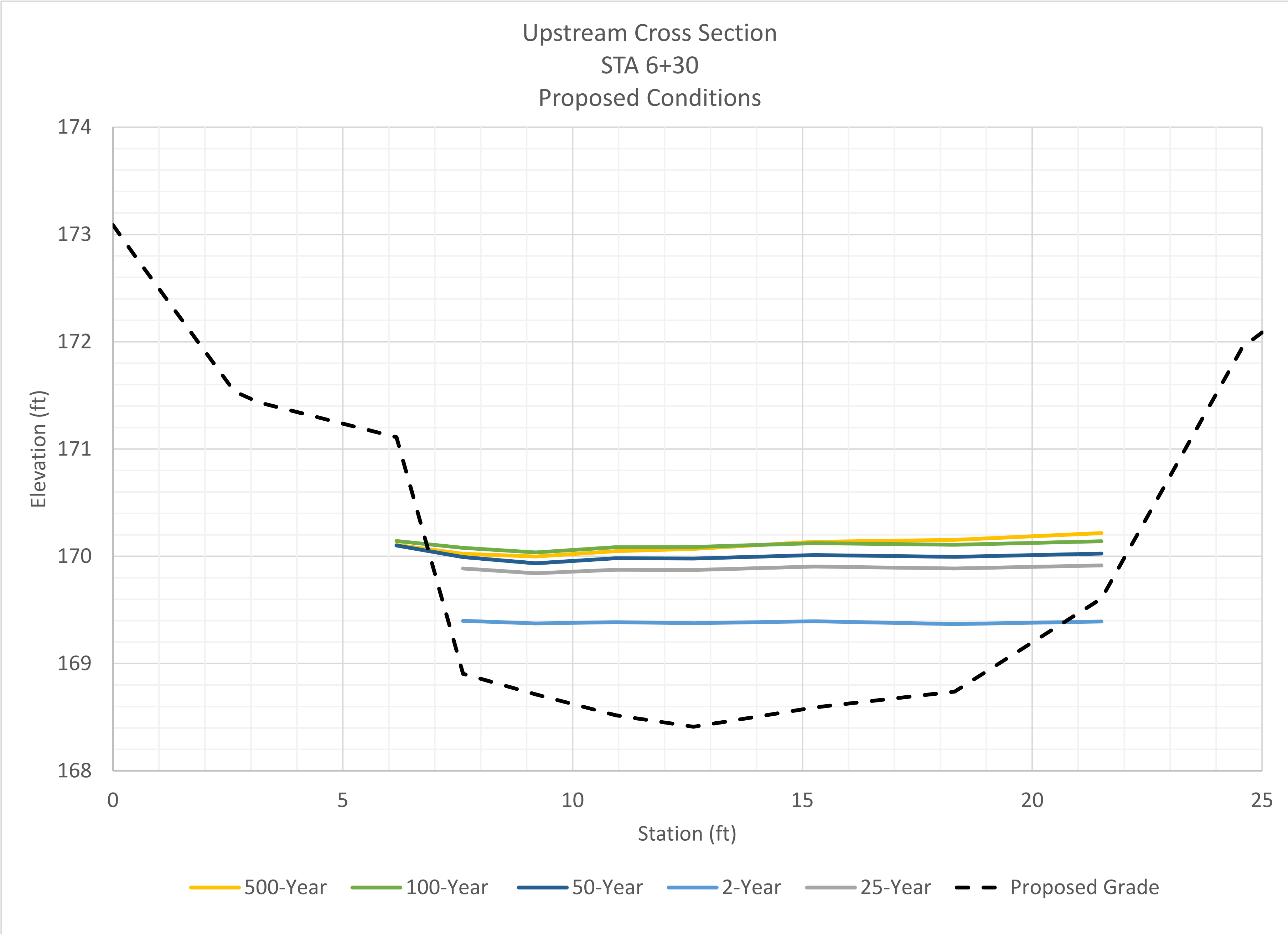
Appendix A – SRH-2D Model Results


Existing WSEL
Elevation (ft)
175
170
165
160
155
150
145
140
7+00
6+00
5+00
4+00
3+00
2+00
1+00
0+00
Existing Ground
2-Year
25-Year
50-Year
100-Year
500-Year
XS

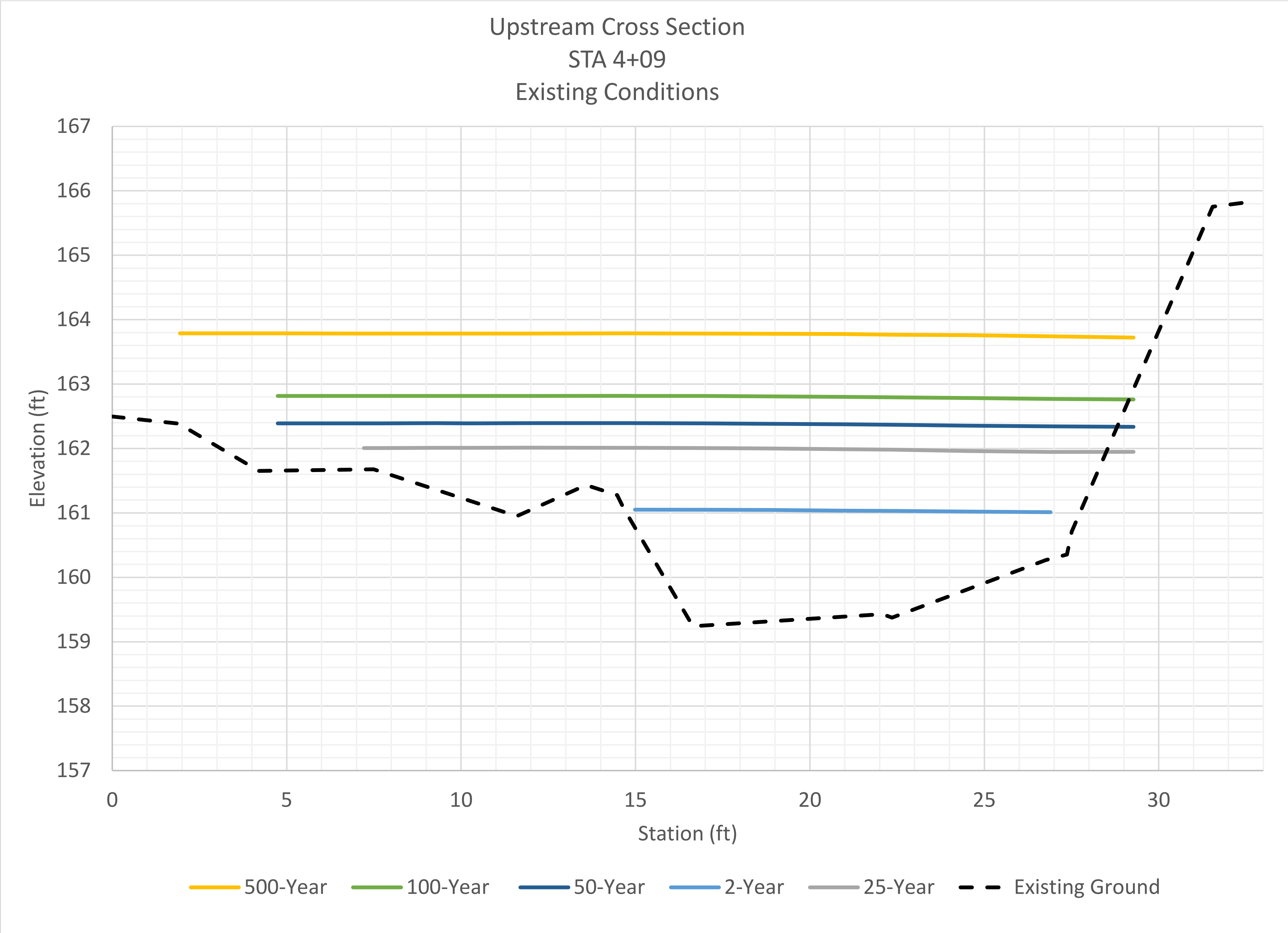

Proposed WSEL
Elevation (ft)
175
170
165
160
155
150
145
140
7+00
6+00
5+00
4+00
3+00
2+00
1+00
0+00
Proposed Grade
Existing Ground
2-Year
25-Year
50-Year
100-Year
500-Year
XS

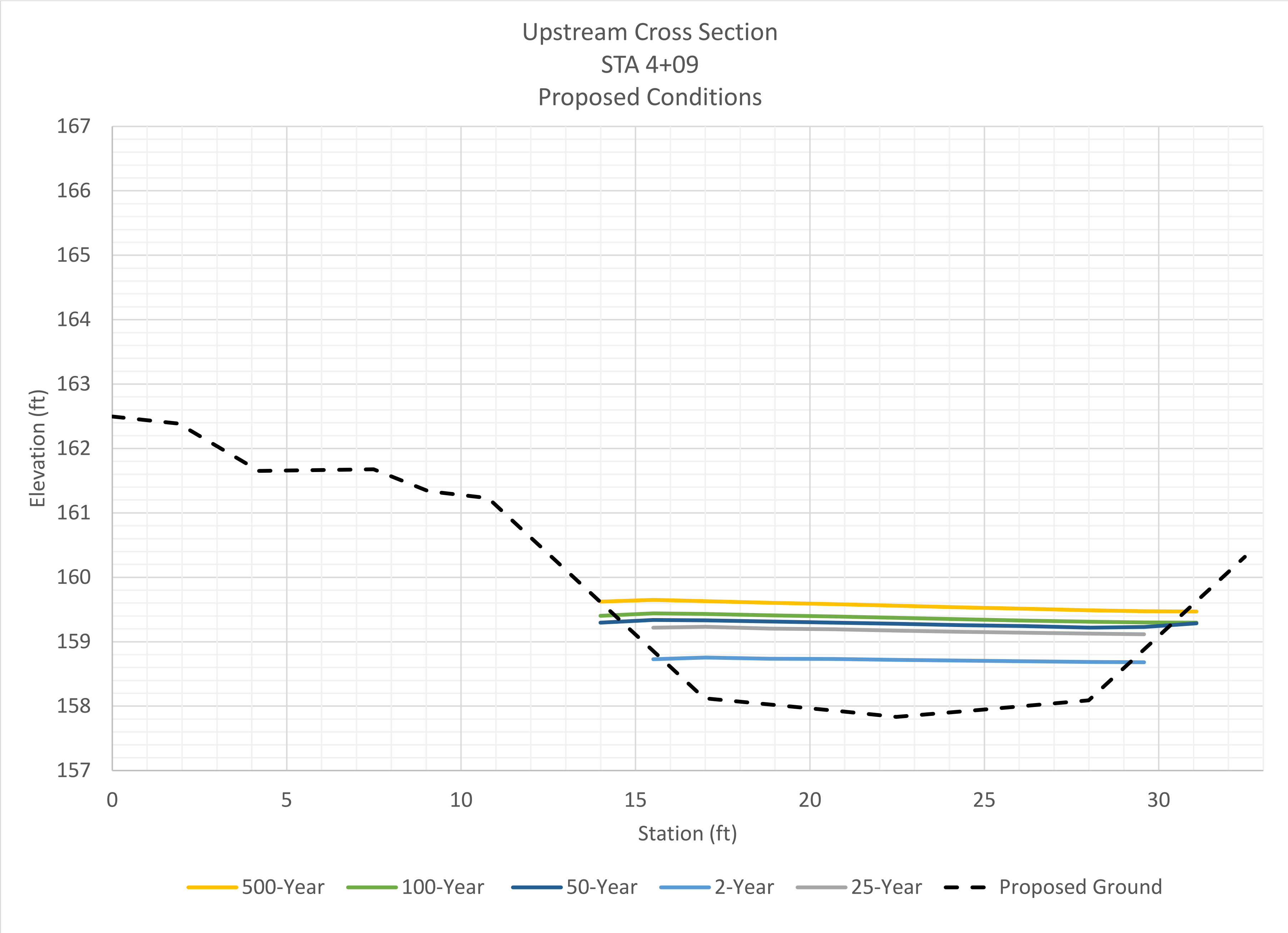


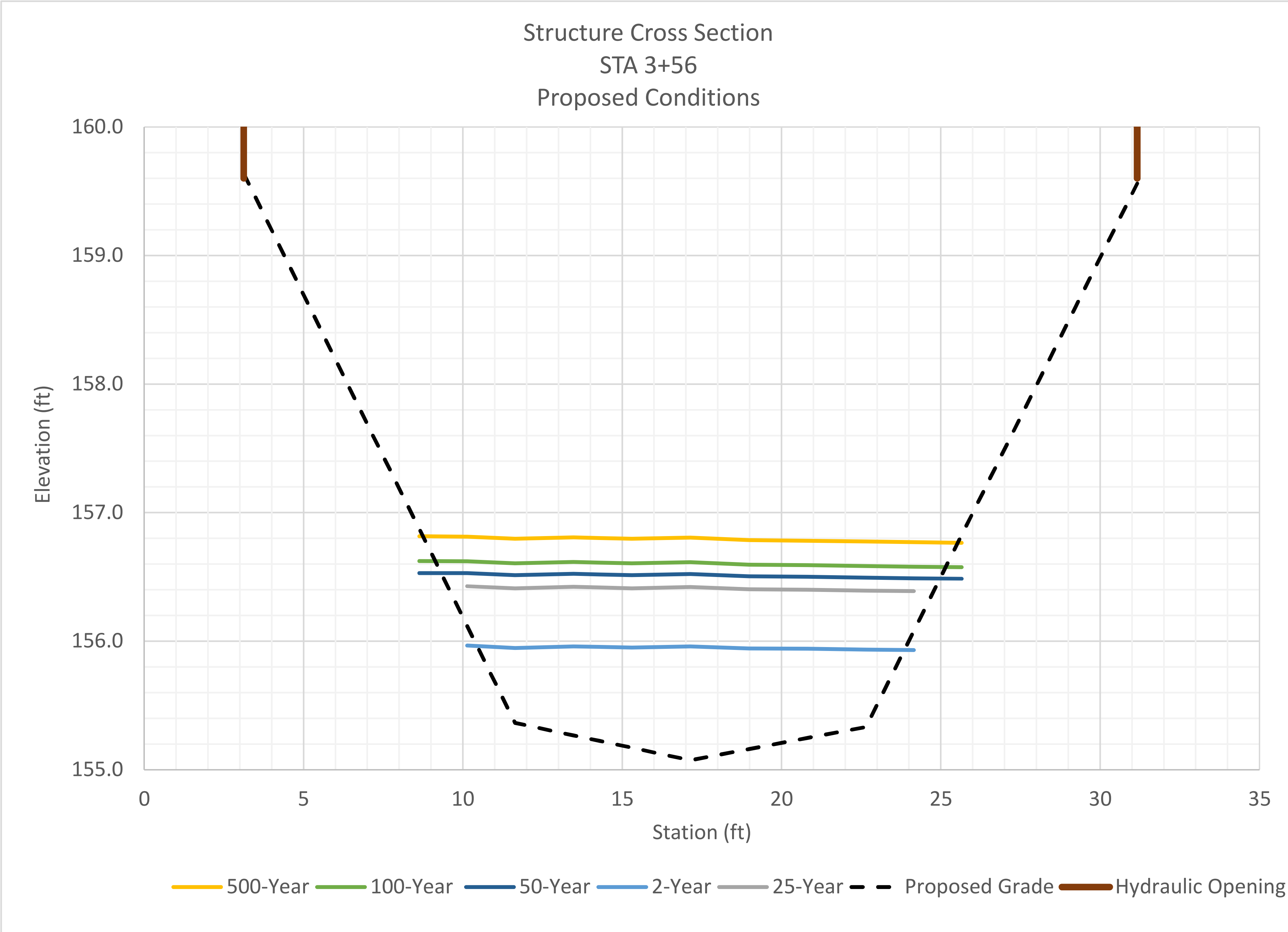
Upstream Cross Section
STA 6+30
Existing Conditions
Elevation (ft)
174
173
172
171
170
169
168
0
5
10
15
20
25
Station (ft)
500-Year
100-Year
50-Year
2-Year
25-Year
Existing Ground

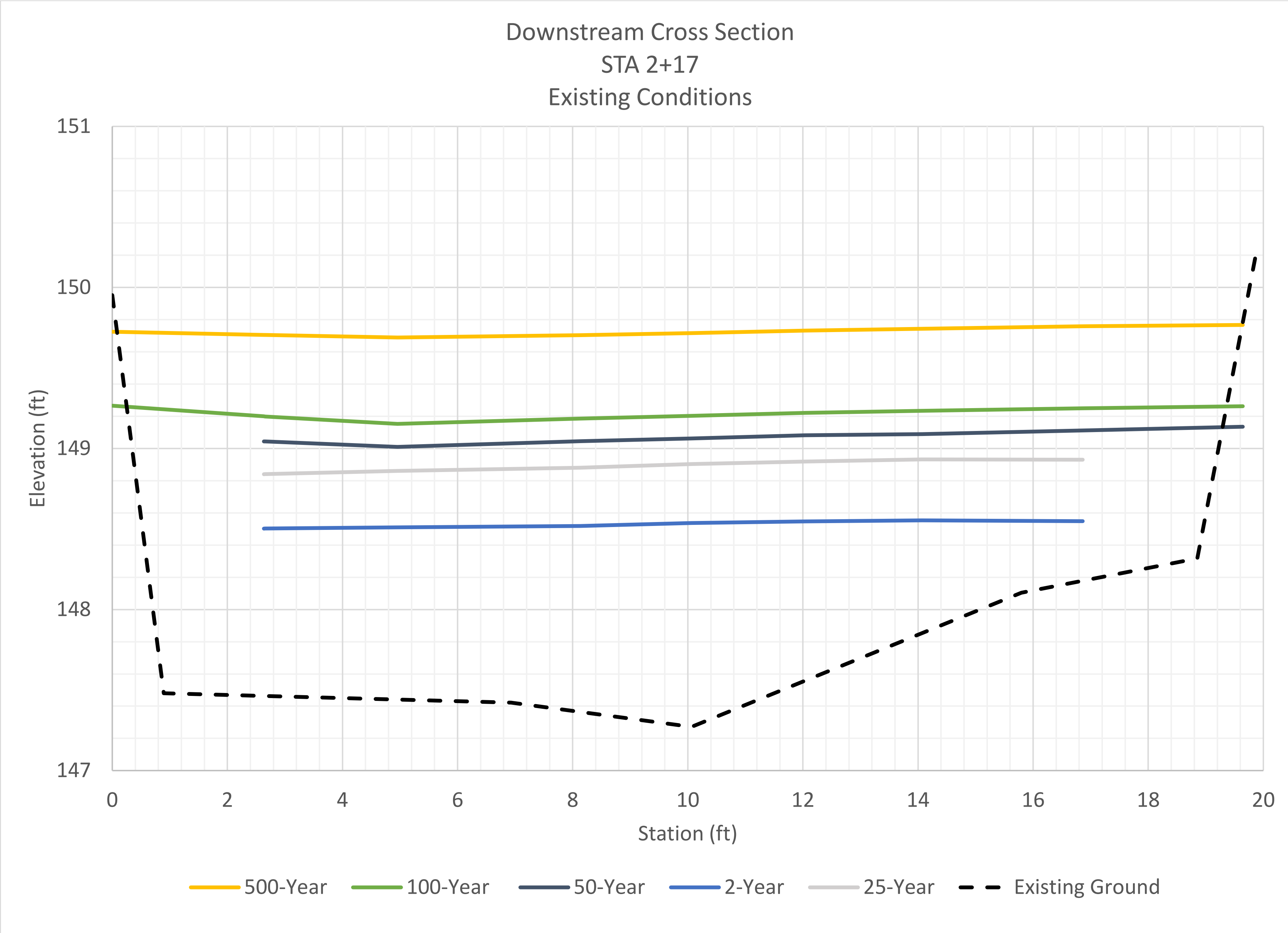


Upstream Cross Section
STA 6+30
Proposed Conditions
174
173
172
171
170
169
168
Elevation (ft)
0
5
10
15
20
25
Station (ft)
500-Year
100-Year
50-Year
2-Year
25-Year
Proposed Grade

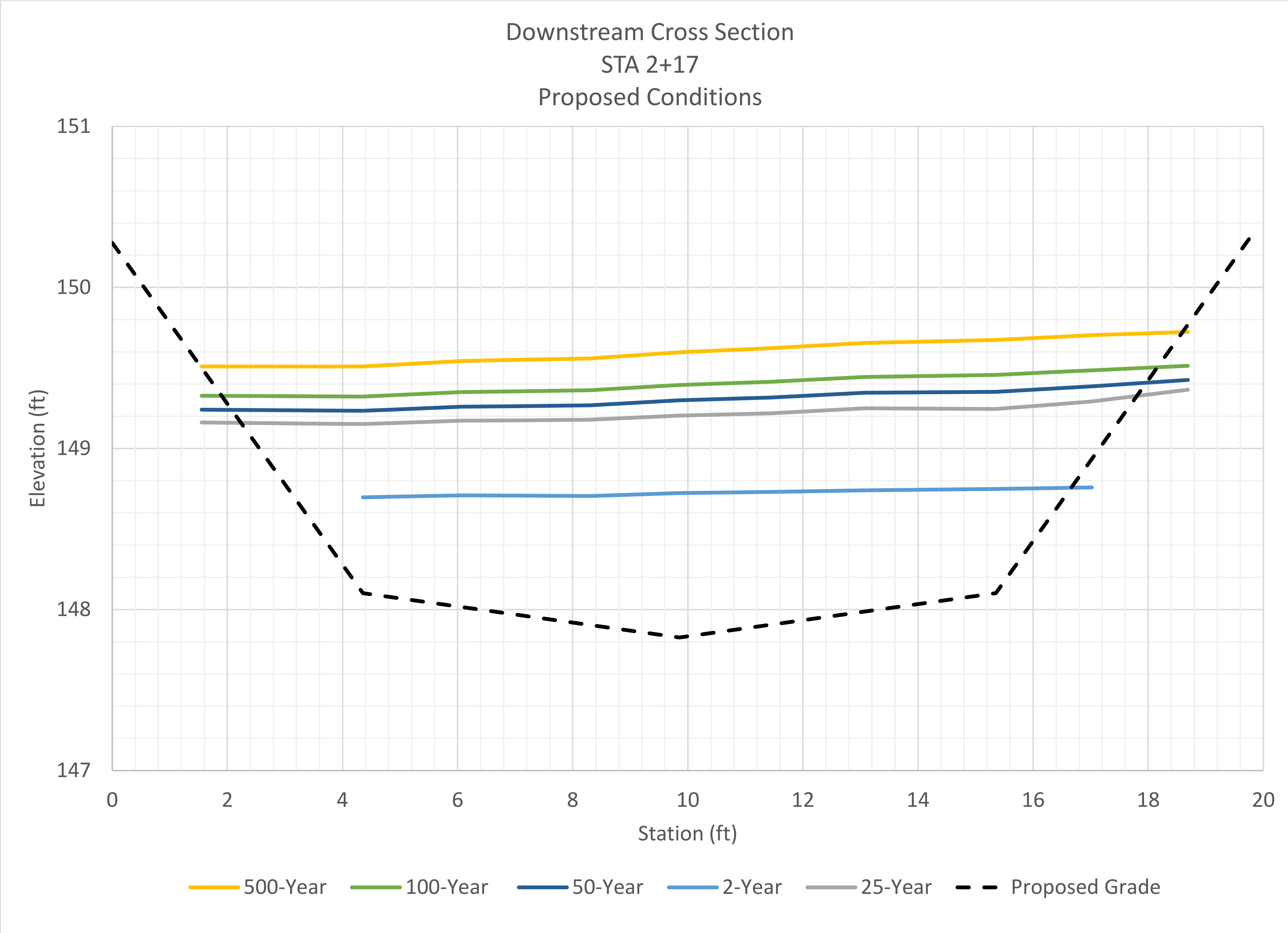

Upstream Cross Section
STA 4+09
Existing Conditions
Elevation (ft)
167
166
165
164
163
162
161
160
159
158
157
0
5
10
15
20
25
30
Station (ft)
500-Year
100-Year
50-Year
2-Year
25-Year
Existing Ground


Upstream Cross Section
STA 4+09
Proposed Conditions
Elevation (ft)
167
166
165
164
163
162
161
160
159
158
157
0
5
10
15
20
25
30
Station (ft)
500-Year
100-Year
50-Year
2-Year
25-Year
Proposed Ground

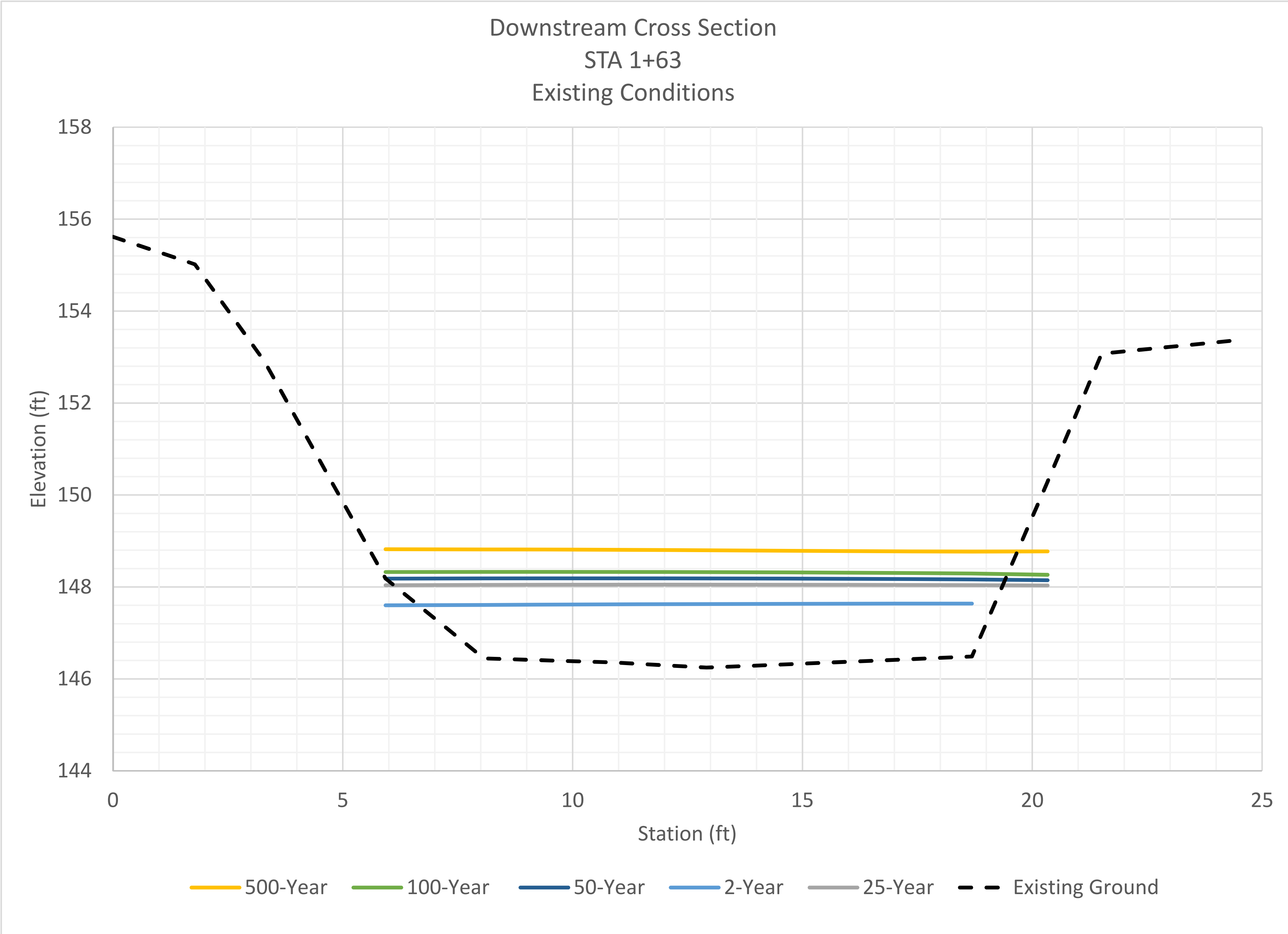

Structure Cross Section
STA 3+56
Proposed Conditions
Elevation (ft)
160.0
159.0
158.0
157.0
156.0
155.0
0
5
10
15
20
25
30
35
Station (ft)
500-Year
100-Year
50-Year
2-Year
25-Year
Proposed Grade
Hydraulic Opening

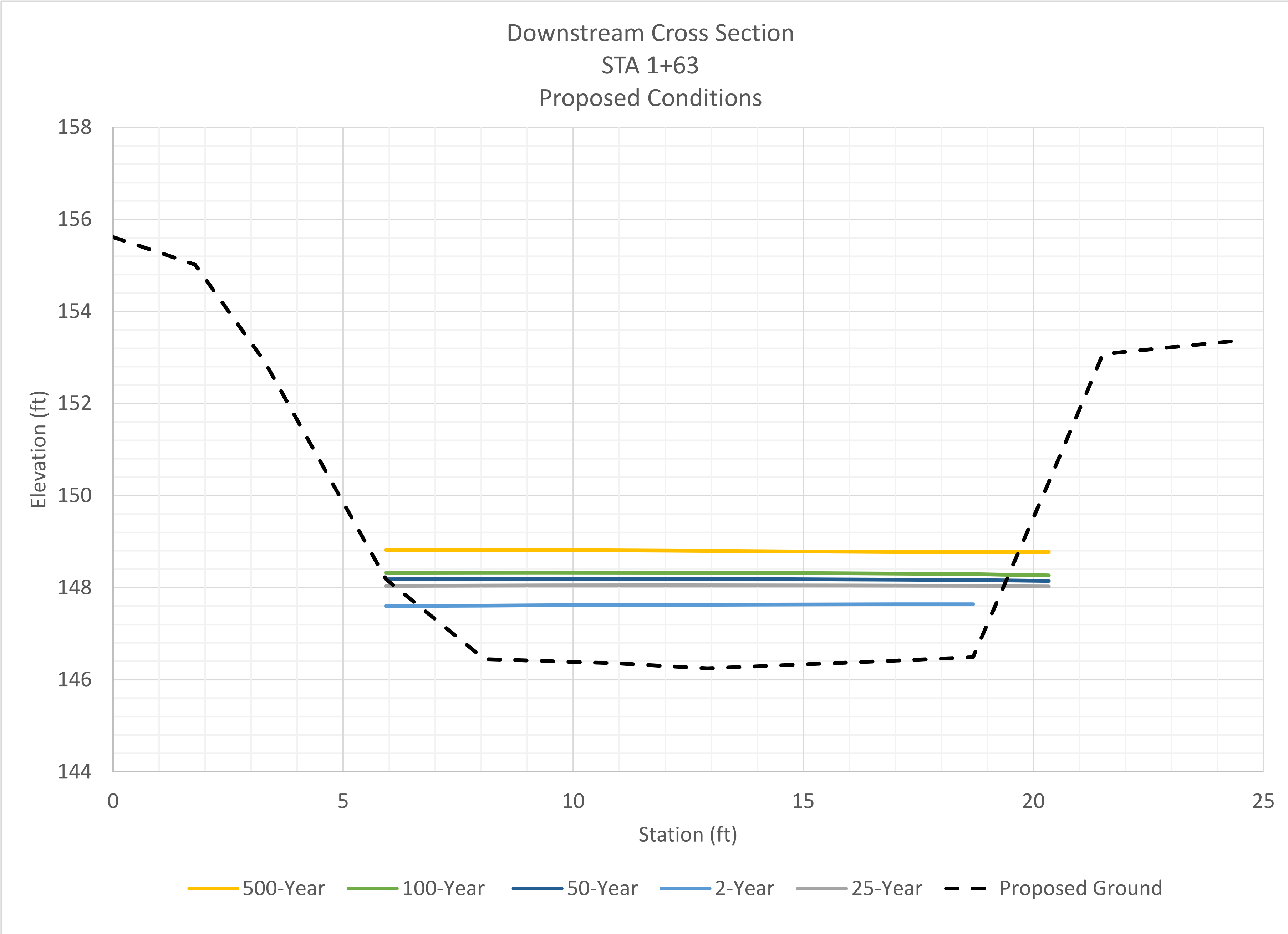


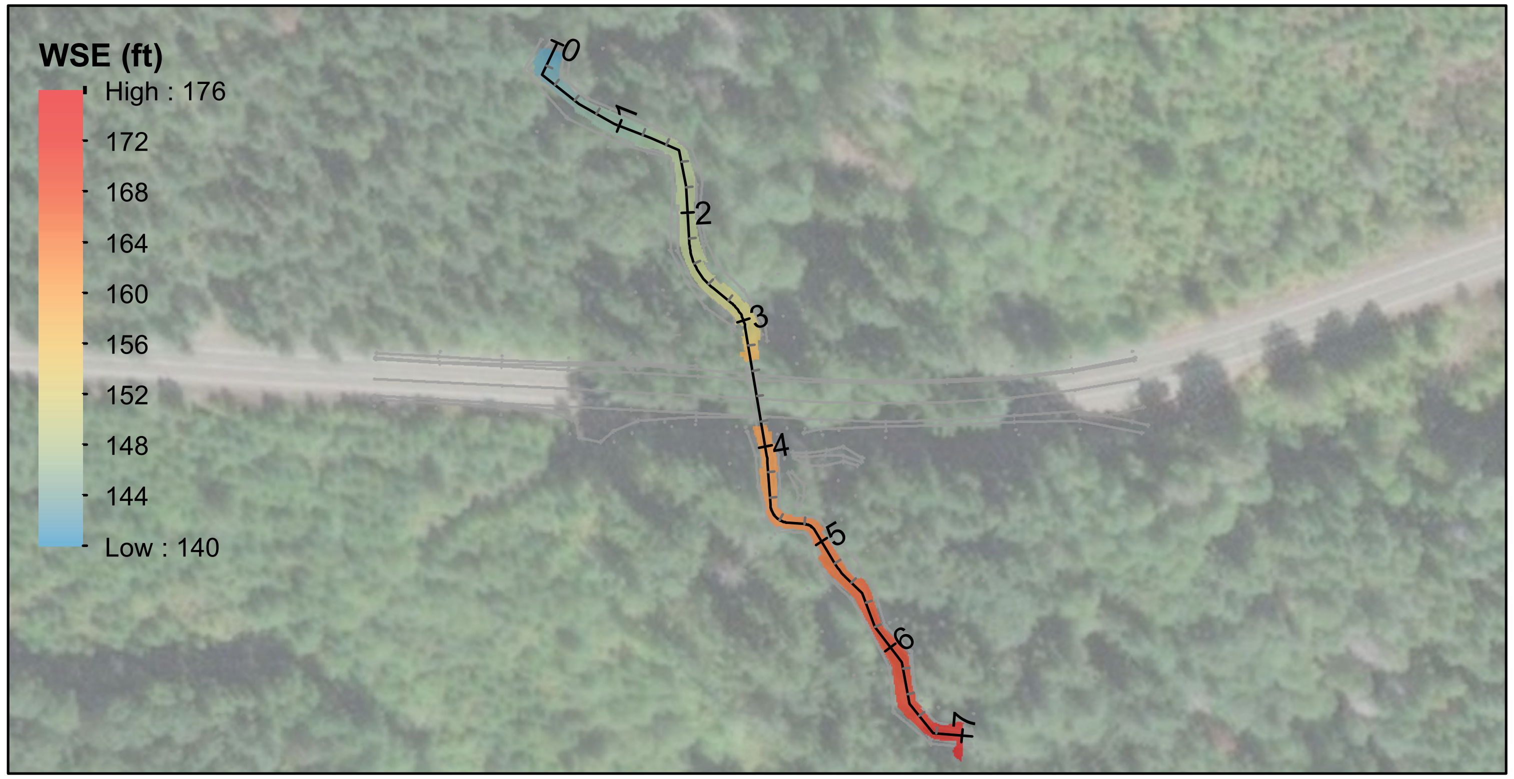
Downstream Cross Section
STA 2+17
Existing Conditions
151
150
149
148
147
Elevation (ft)
0
2
4
6
8
10
12
14
16
18
20
Station (ft)
500-Year
100-Year
50-Year
2-Year
25-Year
Existing Ground



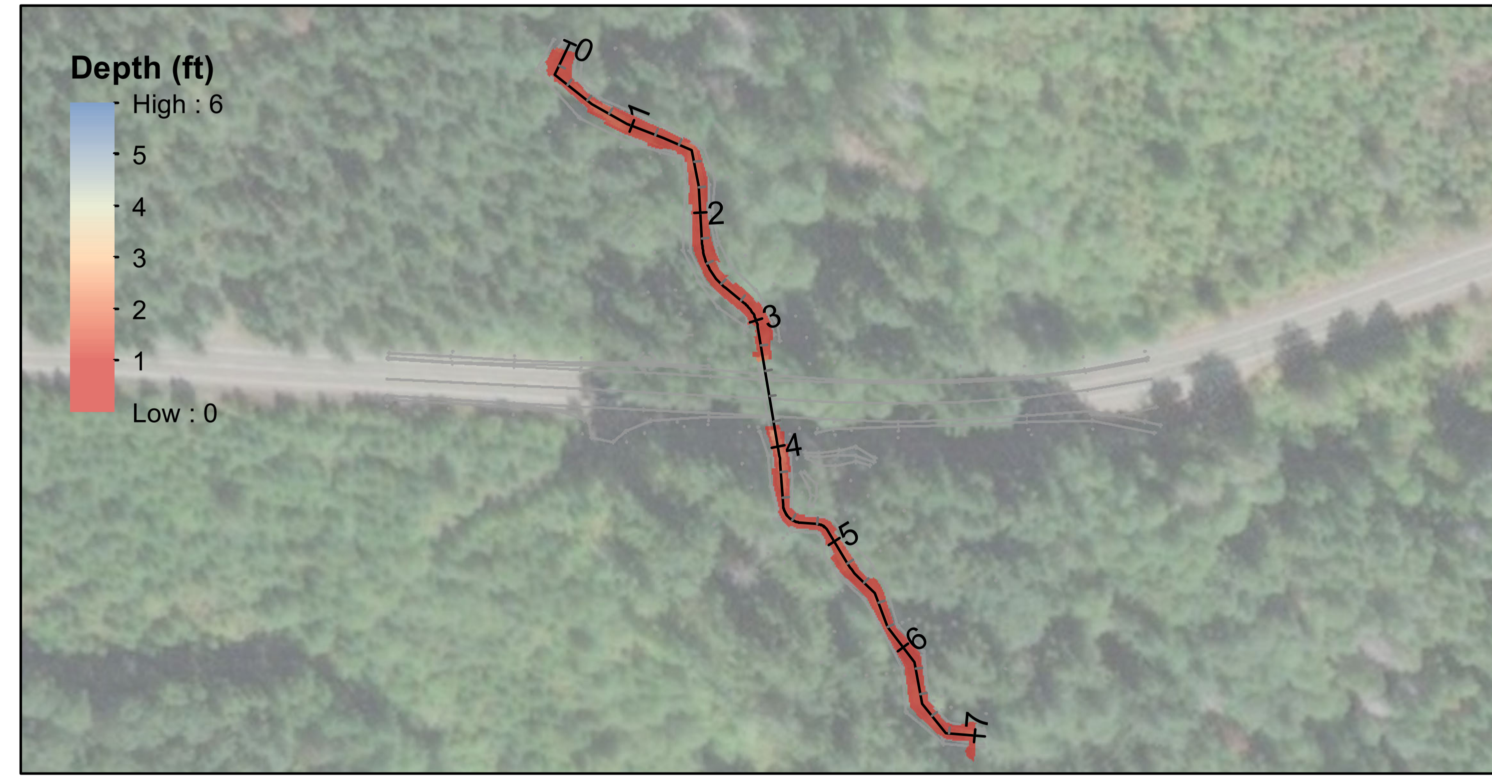
Downstream Cross Section
STA 2+17
Proposed Conditions
151
150
149
148
147
Elevation (ft)
0
2
4
6
8
10
12
14
16
18
20
Station (ft)
500-Year
100-Year
50-Year
2-Year
25-Year
Proposed Grade


Downstream Cross Section
STA 1+63
Existing Conditions
Elevation (ft)
158
156
154
152
150
148
146
144
0
5
10
15
20
25
Station (ft)
500-Year
100-Year
50-Year
2-Year
25-Year
Existing Ground

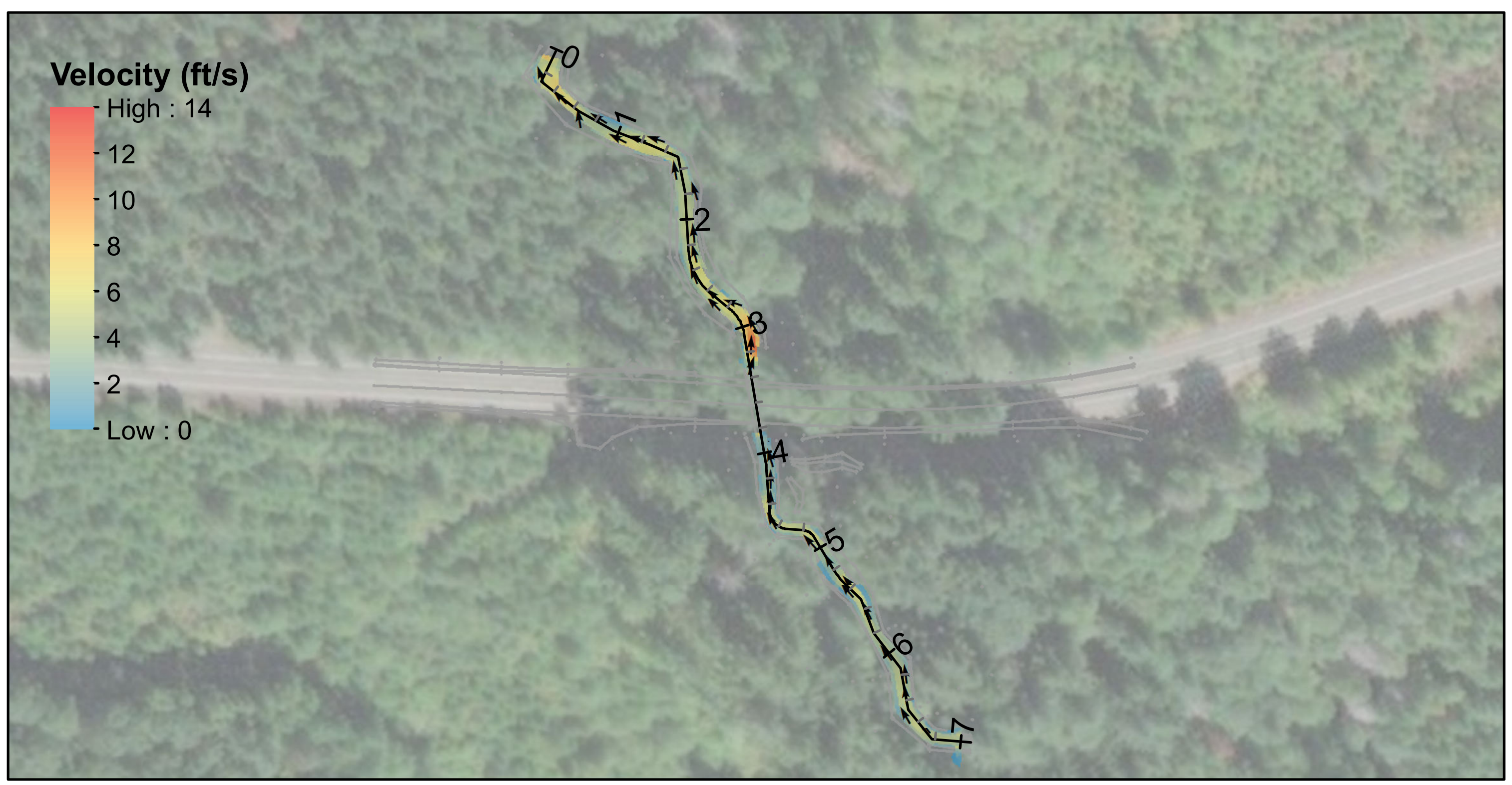

Downstream Cross Section
STA 1+63
Proposed Conditions
Elevation (ft)
158
156
154
152
150
148
146
144
0
5
10
15
20
25
Station (ft)
500-Year
100-Year
50-Year
2-Year
25-Year
Proposed Ground



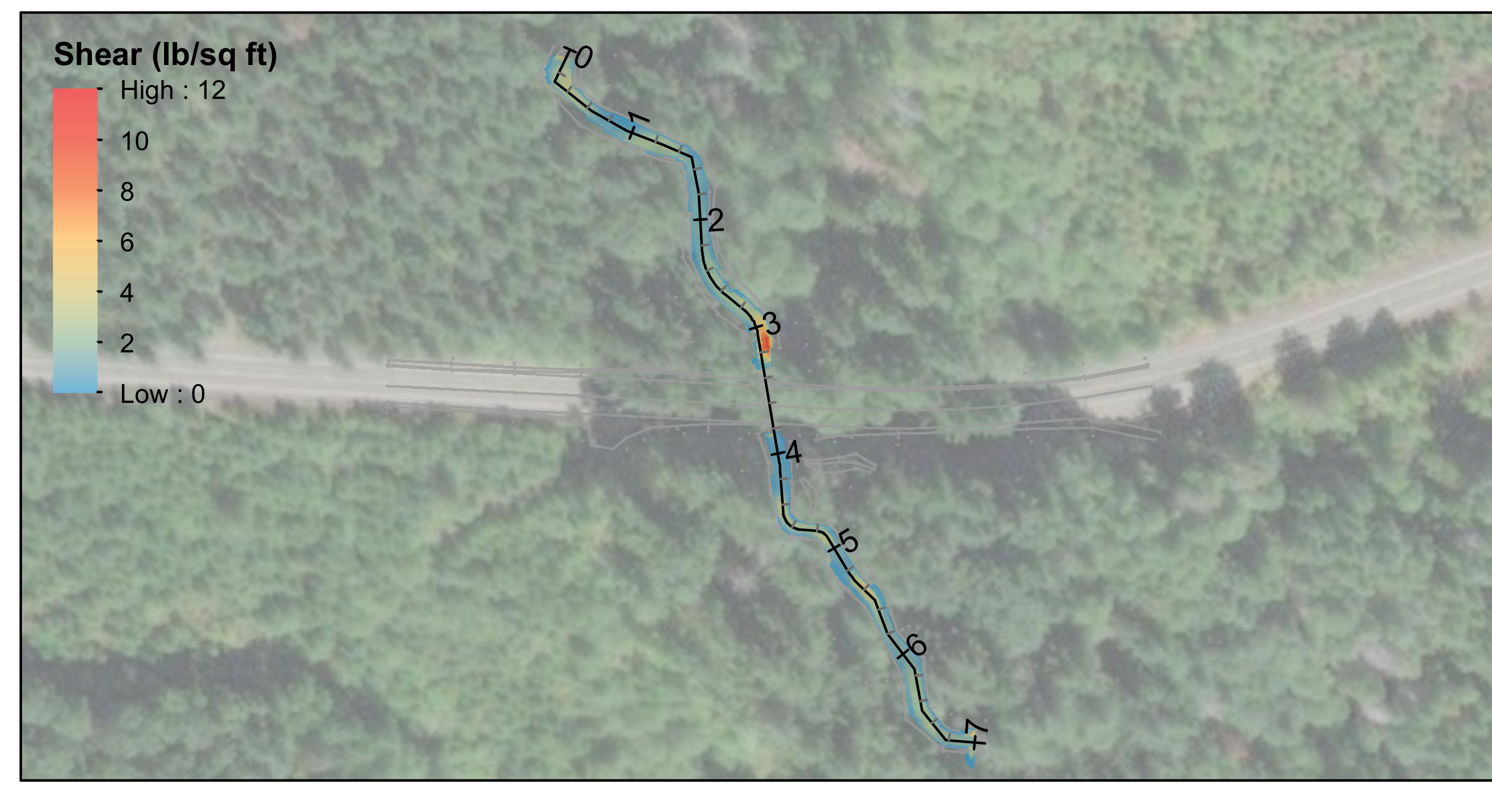
WATER SURFACE ELEVATION



DEPTH



VELOCITY



SHEAR

N

0 100 200 Feet

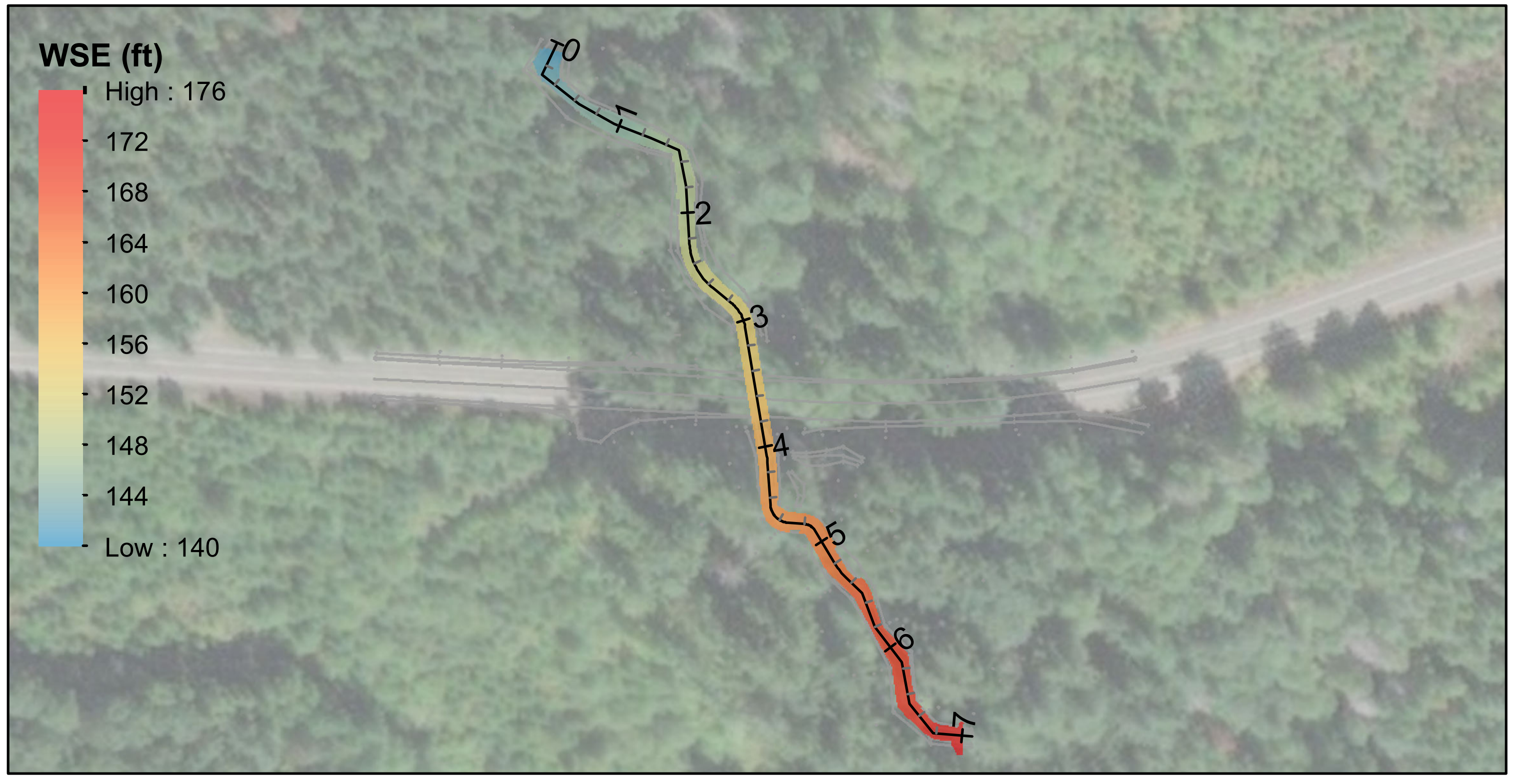
Washington State Department of Transportation

EXISTING CONDITIONS - 2 YEAR EVENT

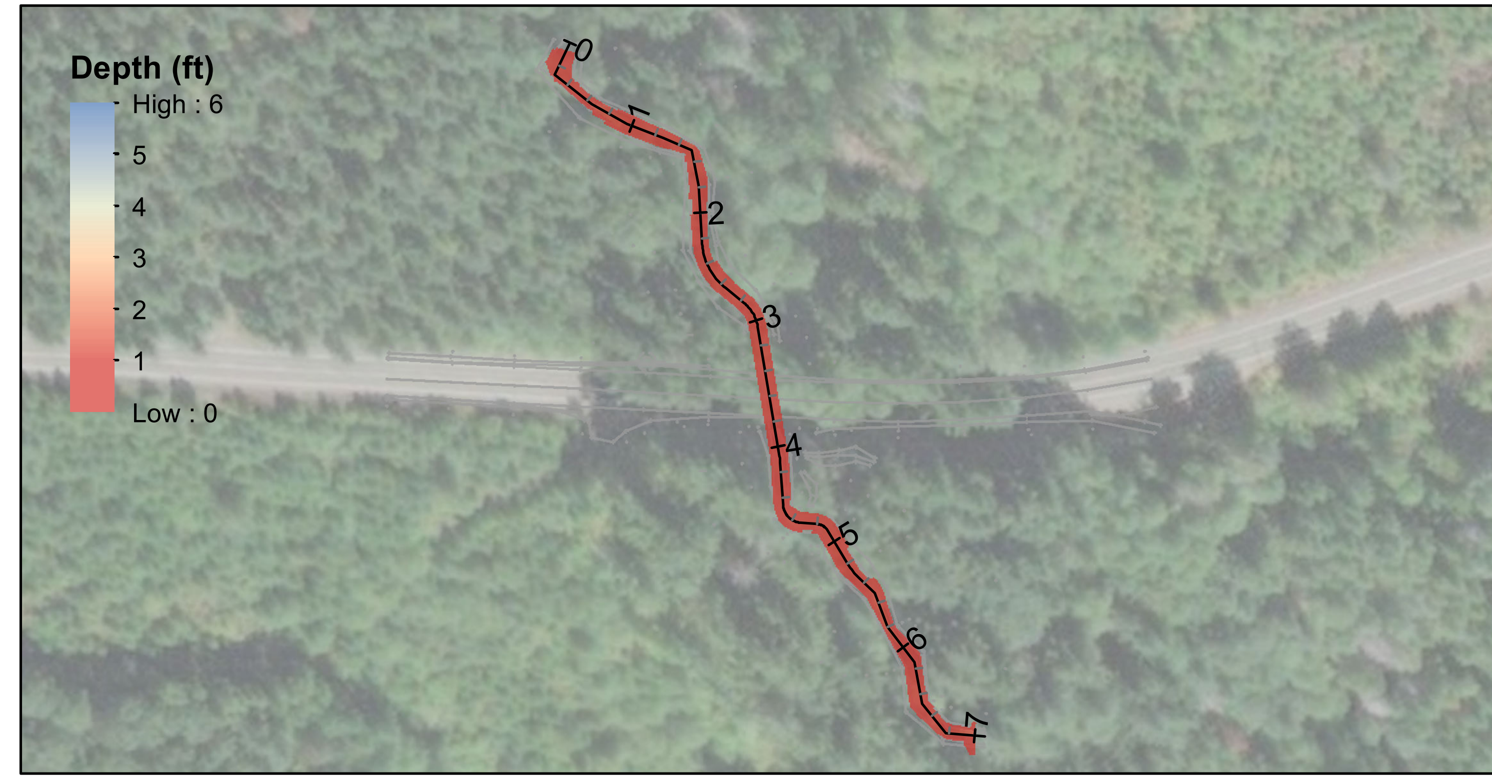
SR 108 UNNAMED TRIBUTARY TO SKOOKUM CREEK
MP 7.62

PATH: S:\SR108\MP7.62 WDFW ID 991672 UNT TO SKOOKUM\3_EX_QC_AND_PROPOSED_QC_COMMENTS_ADDRESSED\SR108_MP7.62\MODEL\RESULTS\OUTPUT FIGURES\EXISTING_2YR FINAL.MXD - USER: DMINNER - DATE: 10/3/2019

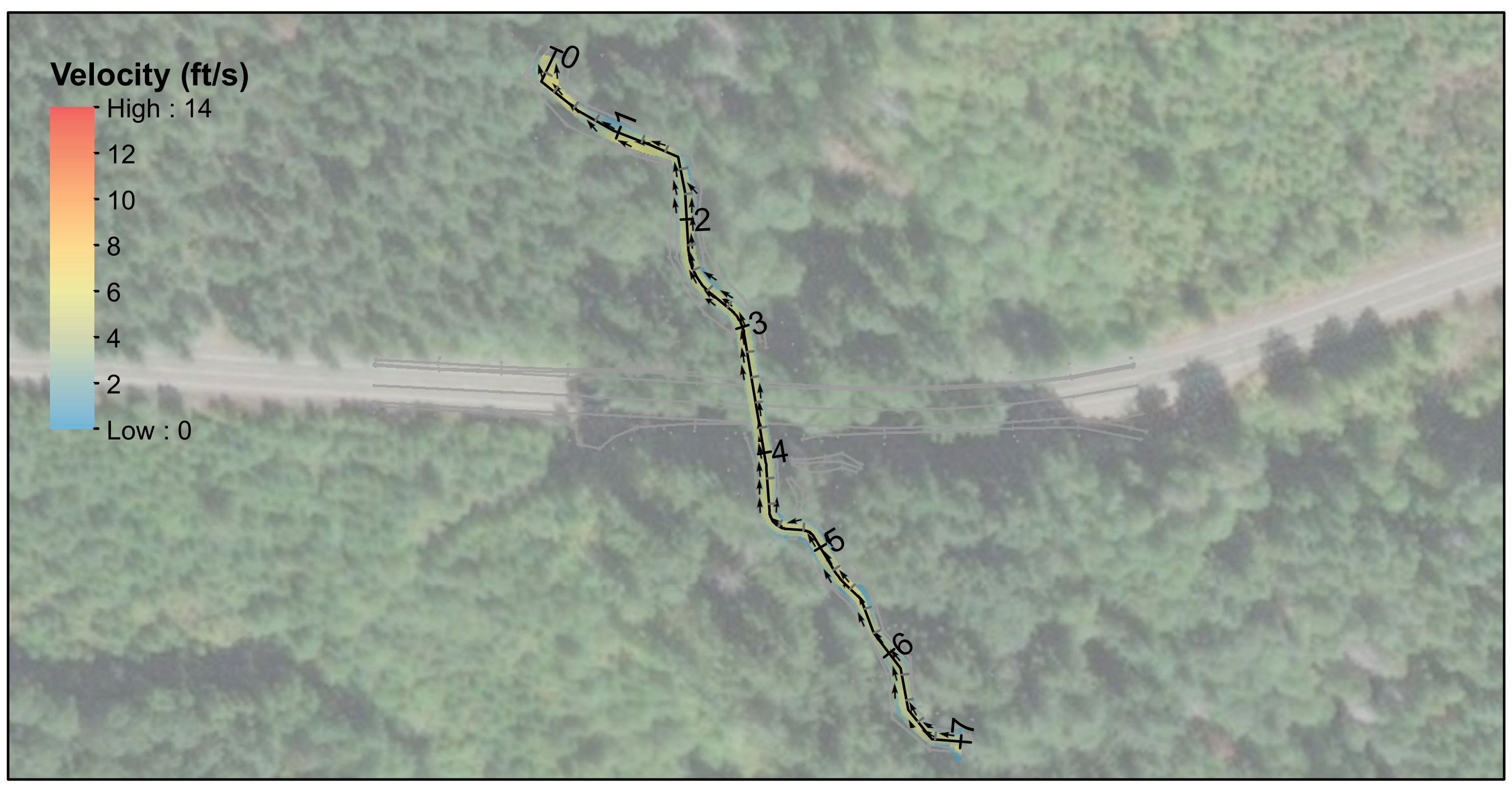
PRELIMINARY HYDARULIC DESIGN



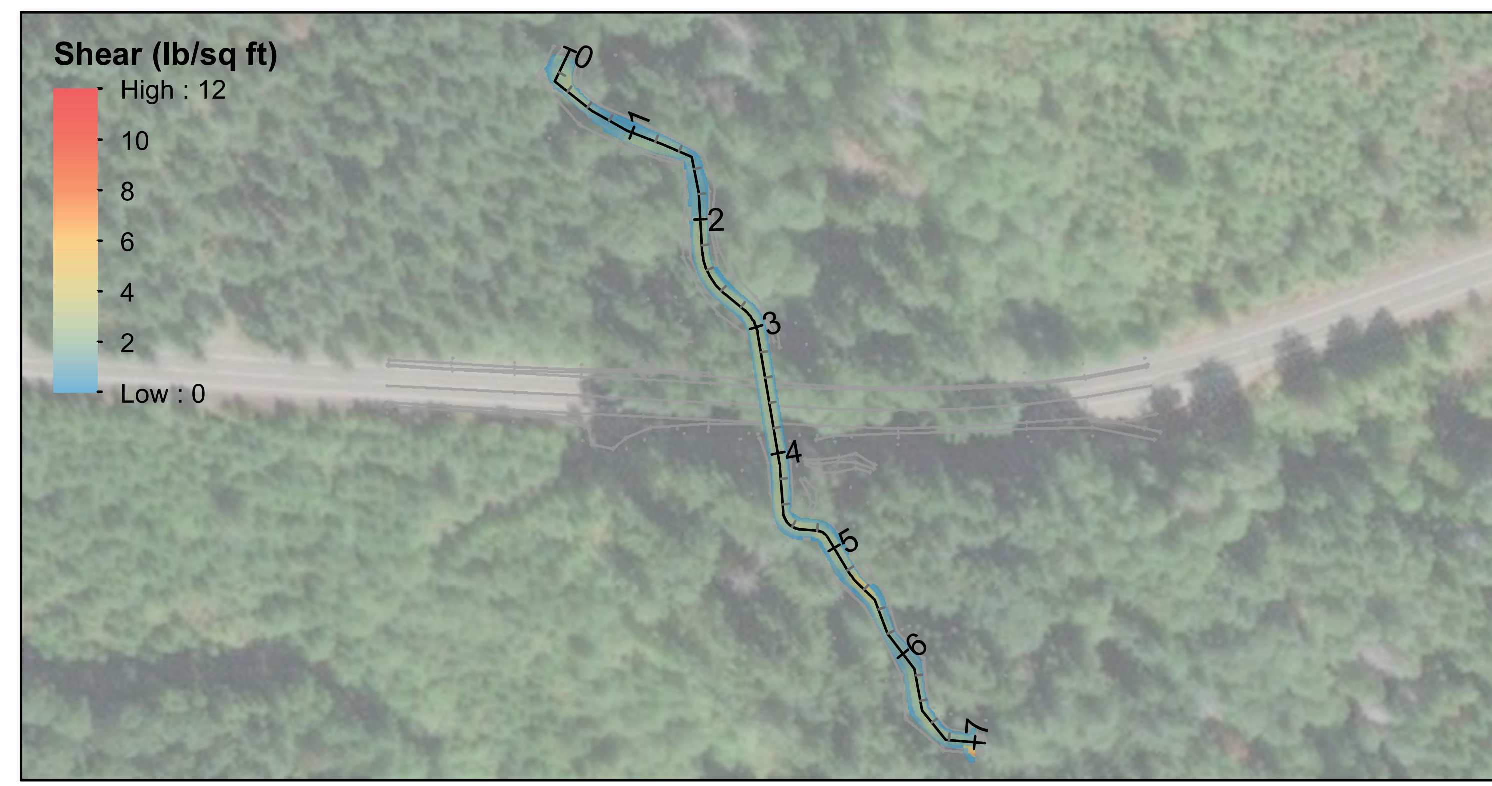
WATER SURFACE ELEVATION



DEPTH



VELOCITY



SHEAR

N

0 100 200 Feet

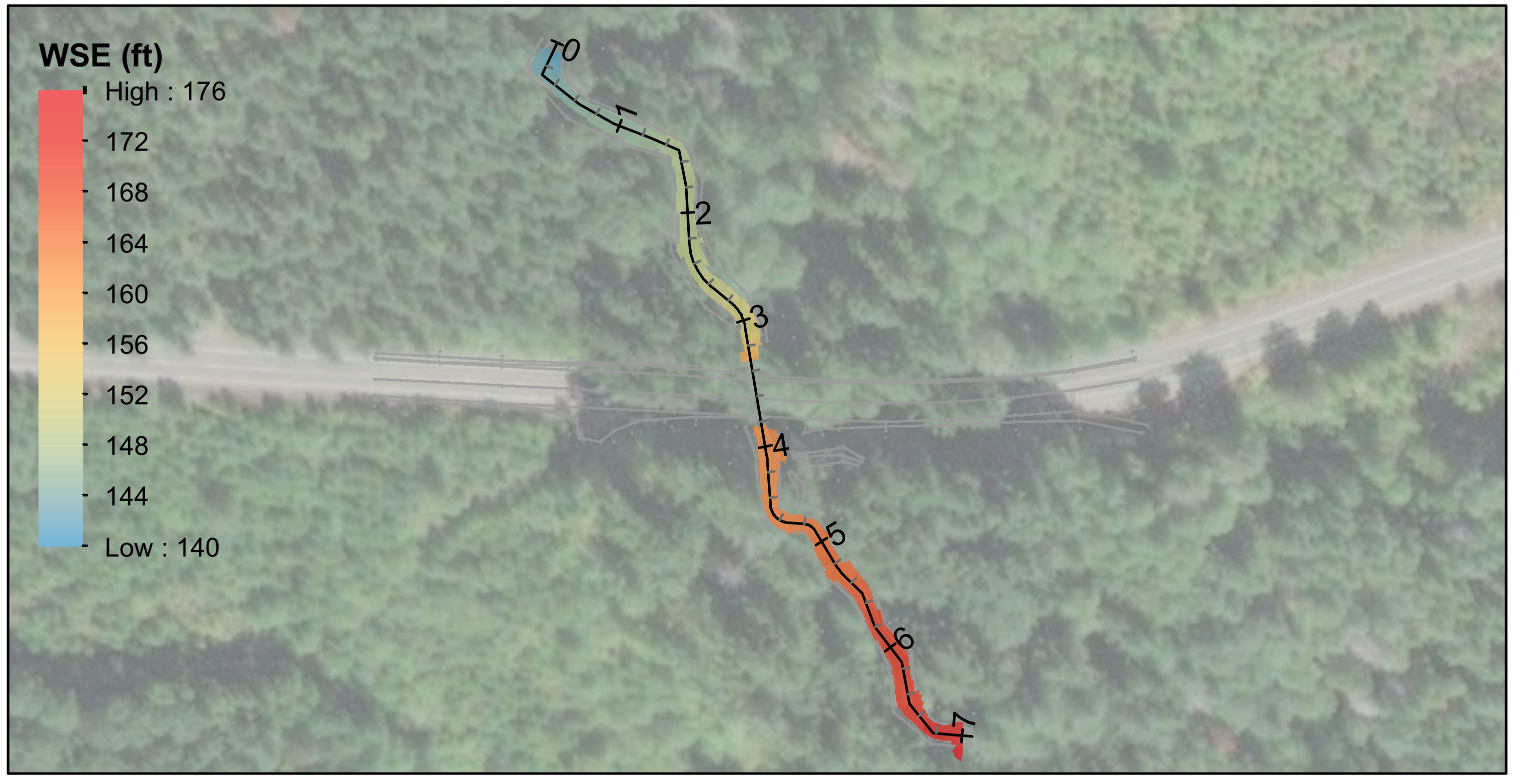
Washington State Department of Transportation

PROPOSED CONDITIONS - 2 YEAR EVENT

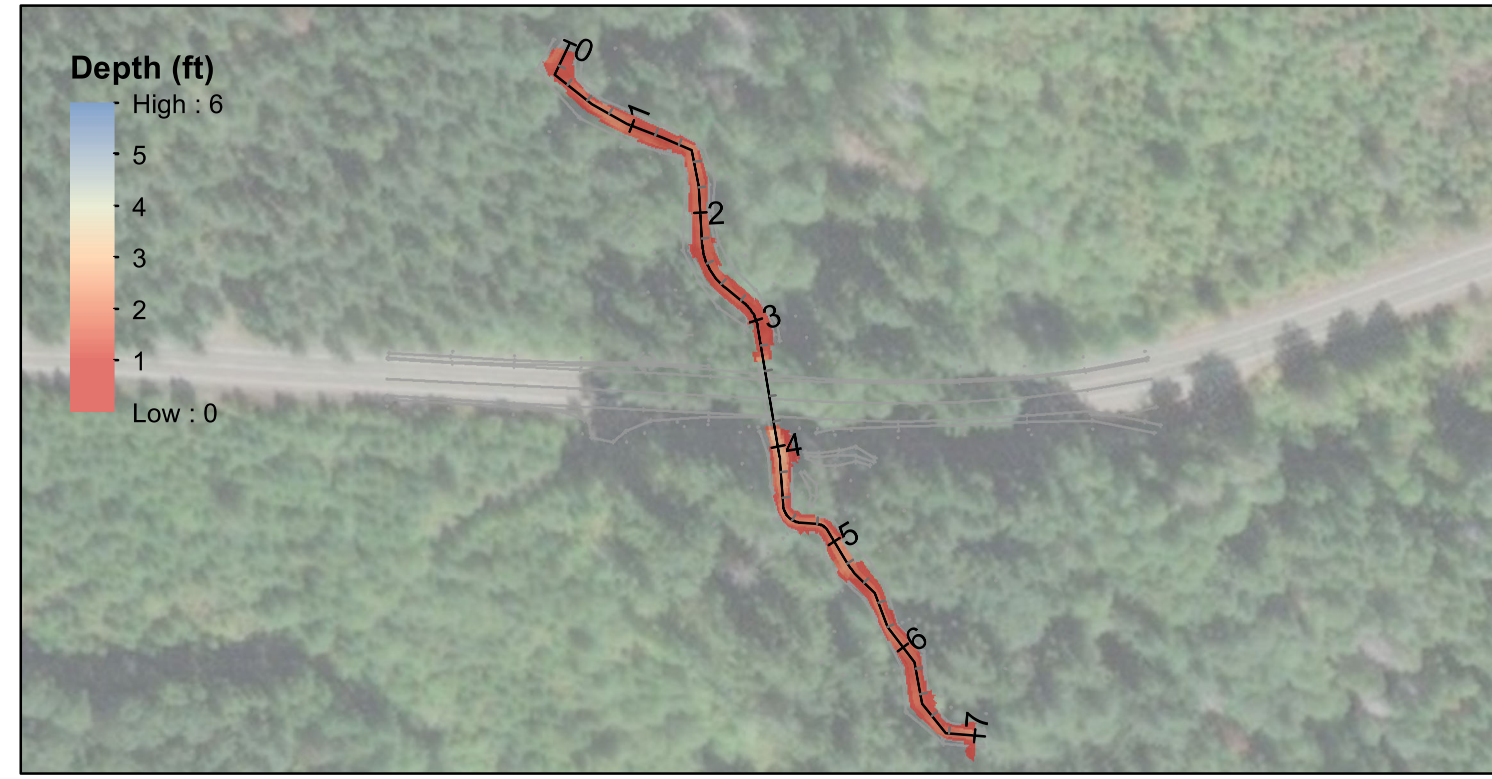
SR 108 UNNAMED TRIBUTARY TO SKOOKUM CREEK
MP 7.62

PATH: S:\SR108\MP7.62 WDFW ID 991672 UNT TO SKOOKUM\3_EX_QC_AND_PROPOSED_QC_COMMENTS_ADDRESSED\SR108_MP7.62\MODEL\RESULTS\OUTPUT FIGURES\PROPOSED_2YR FINAL.MXD - USER: DMINNER - DATE: 10/3/2019

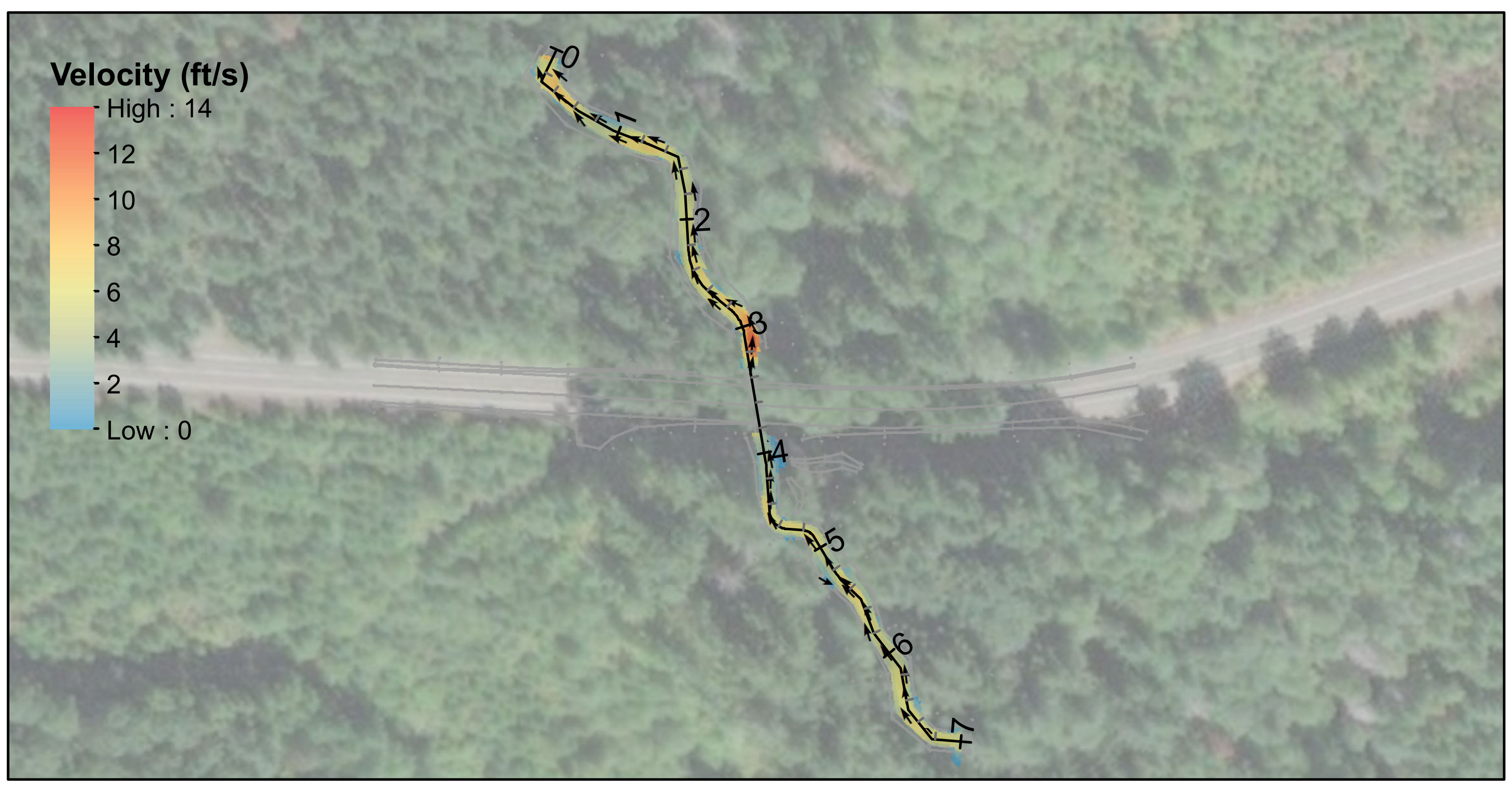
PRELIMINARY HYDARULIC DESIGN



WATER SURFACE ELEVATION



DEPTH



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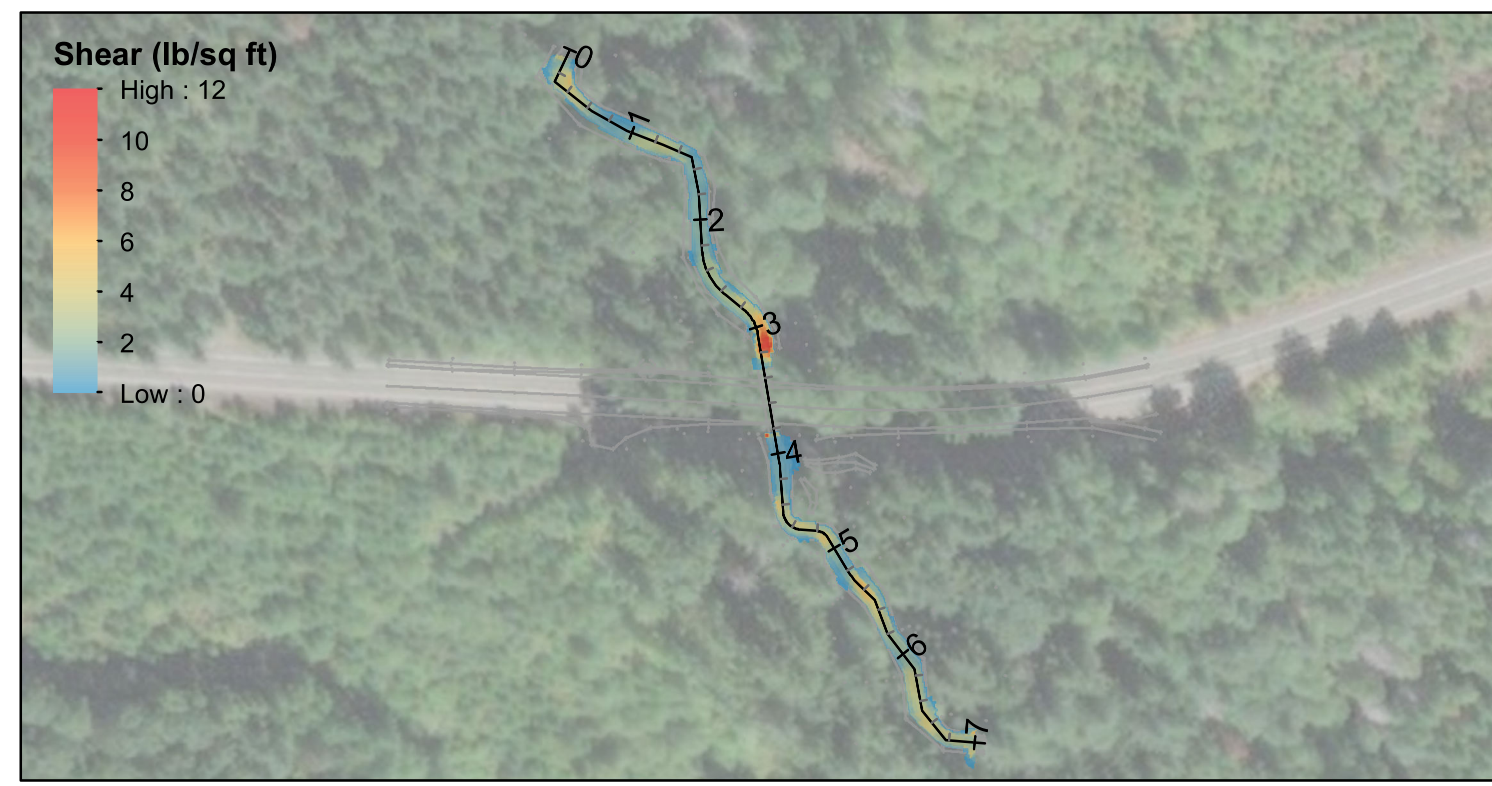

SHEAR

N

0 100 200 Feet

HDR

Washington State Department of Transportation

EXISTING CONDITIONS - 25 YEAR EVENT

SR 108 UNNAMED TRIBUTARY TO SKOOKUM CREEK
MP 7.62

PATH: S:\SR108\MP7.62 WDFW ID 991672 UNT TO SKOOKUM\3_EX_QC_AND_PROPOSED_QC_COMMENTS_ADDRESSED\SR108_MP7.62\MODEL\RESULTS\OUTPUT FIGURES\EXISTING_25YR FINAL.MXD - USER: DMINNER - DATE: 10/3/2019

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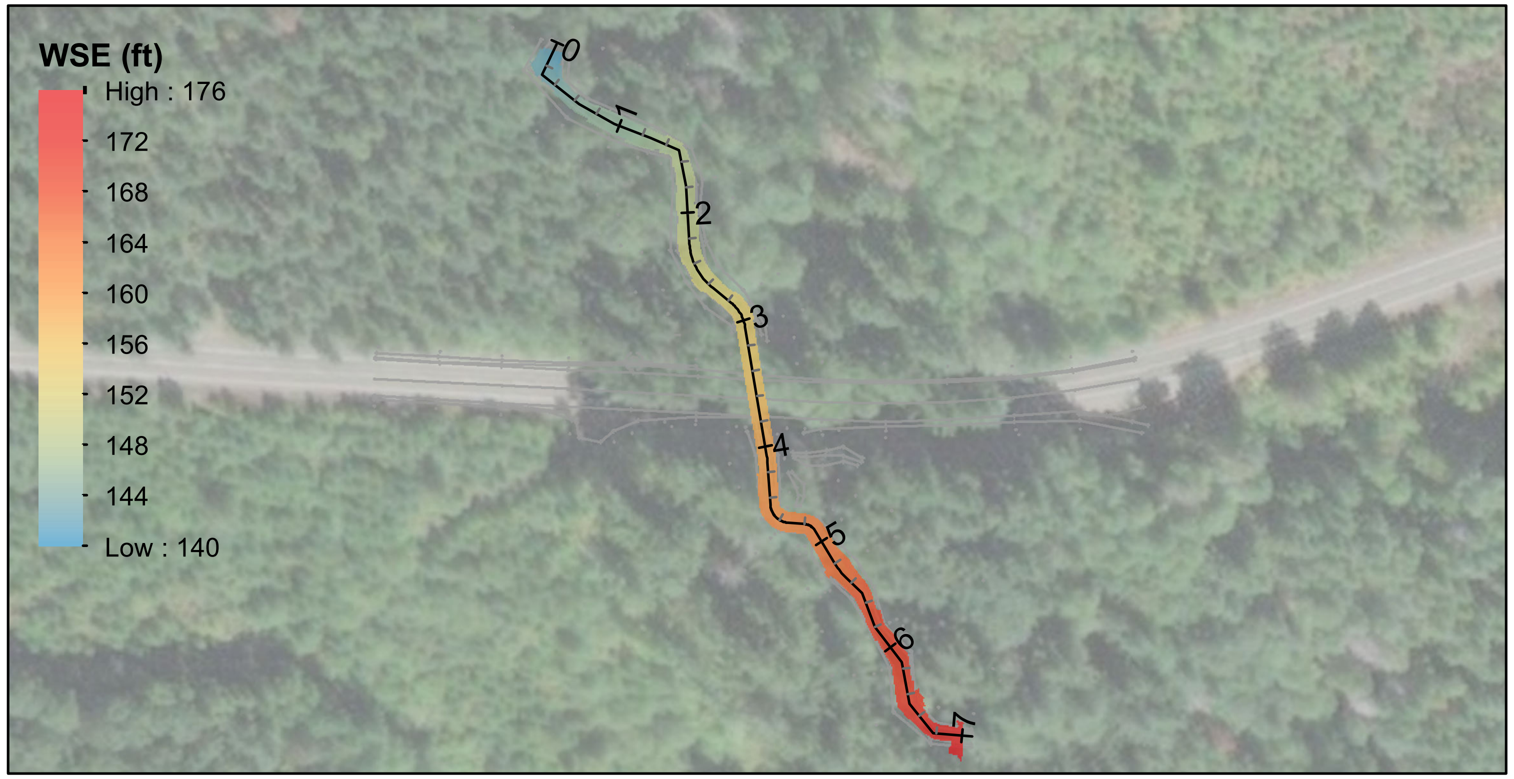
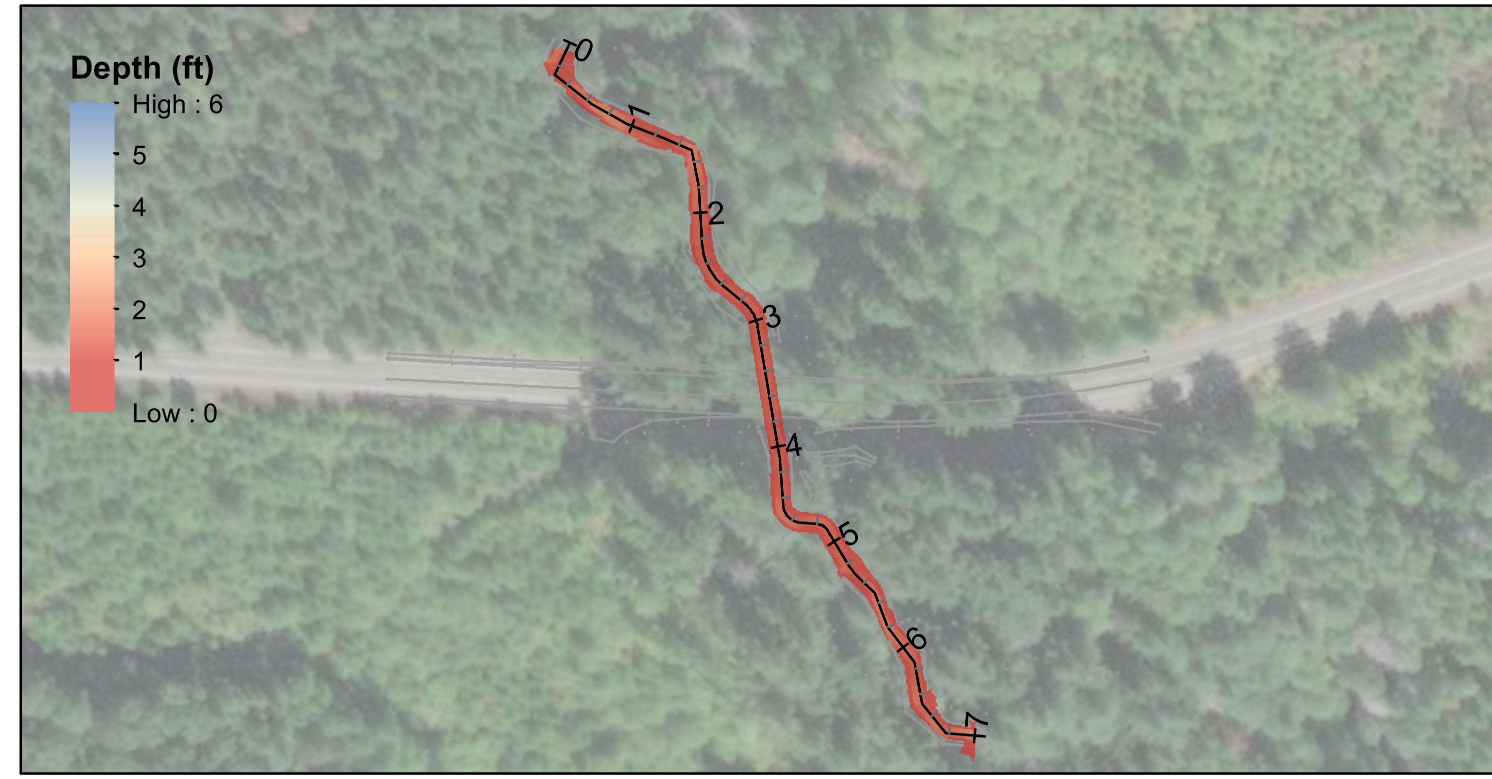
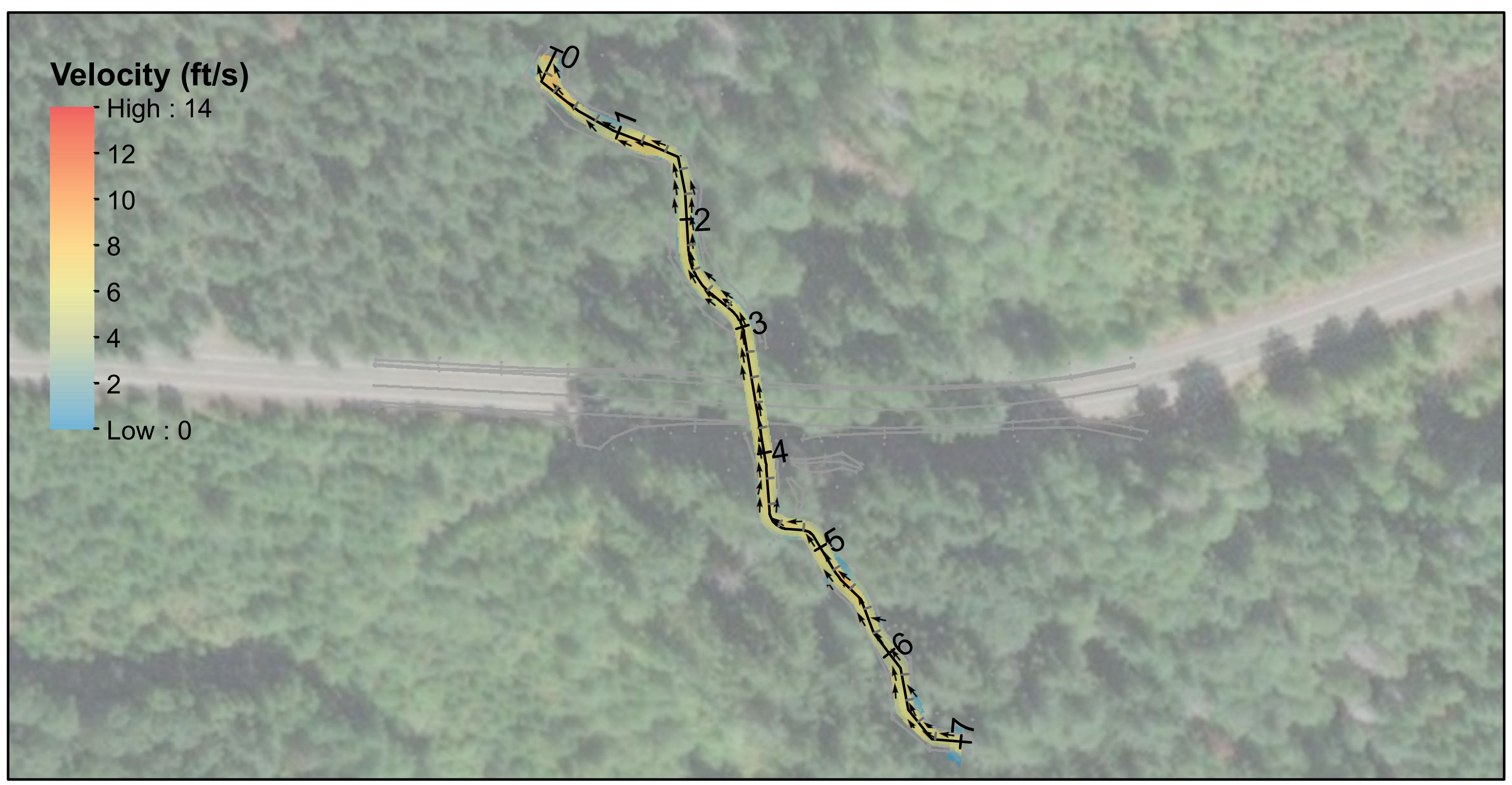


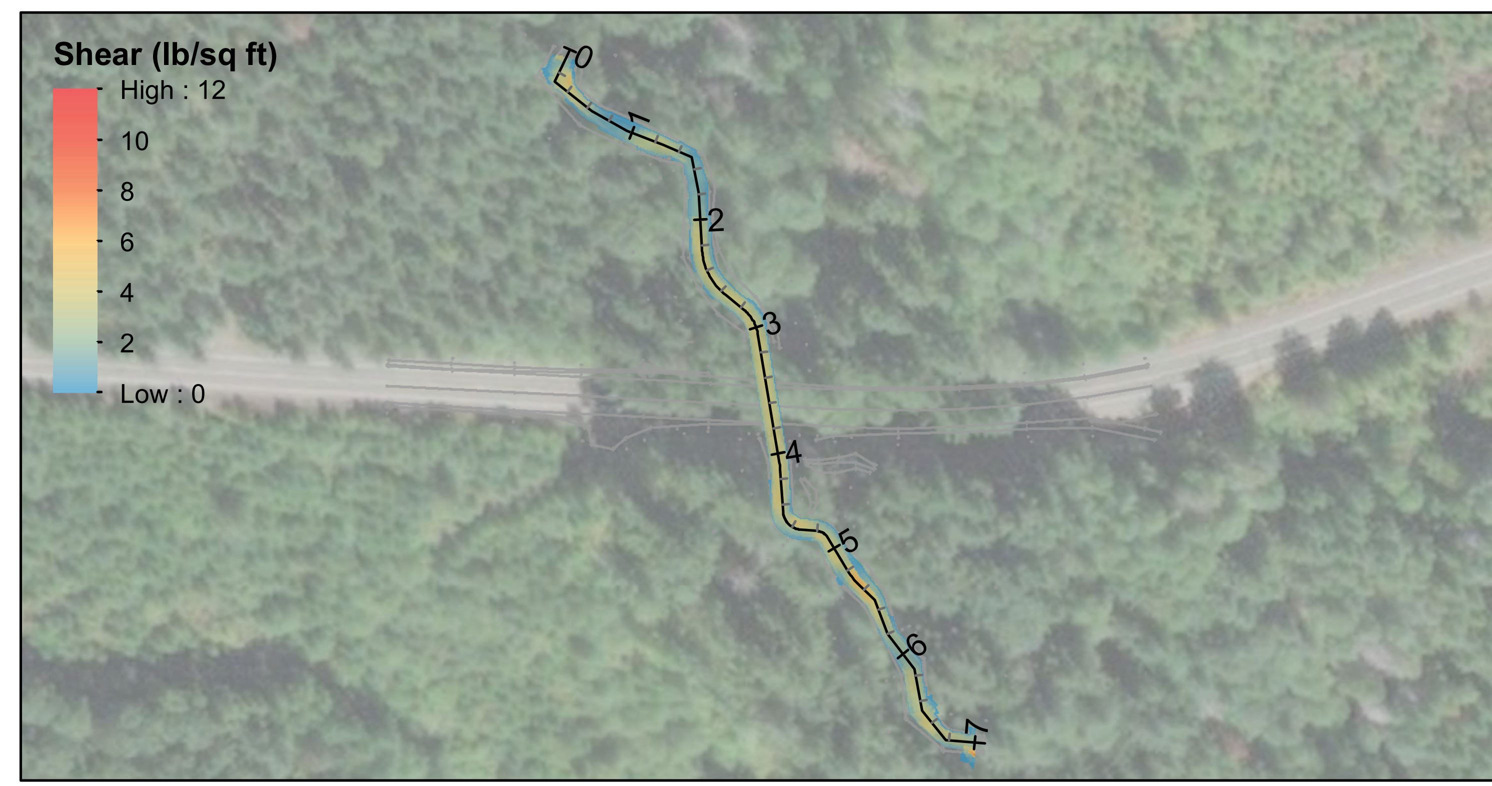
WATER SURFACE ELEVATION



DEPTH



VELOCITY



SHEAR

N

0 100 200 Feet

Washington State Department of Transportation

PROPOSED CONDITIONS - 25 YEAR EVENT

SR 108 UNNAMED TRIBUTARY TO SKOOKUM CREEK
MP 7.62

PATH: S:\SR108\MP7.62 WDFW ID 991672 UNT TO SKOOKUM\3_EX_QC_AND_PROPOSED_QC_COMMENTS_ADDRESSED\SR108_MP7.62\MODEL\RESULTS\OUTPUT FIGURES\PROPOSED_25YR FINAL.MXD - USER: DMINNER - DATE: 10/3/2019

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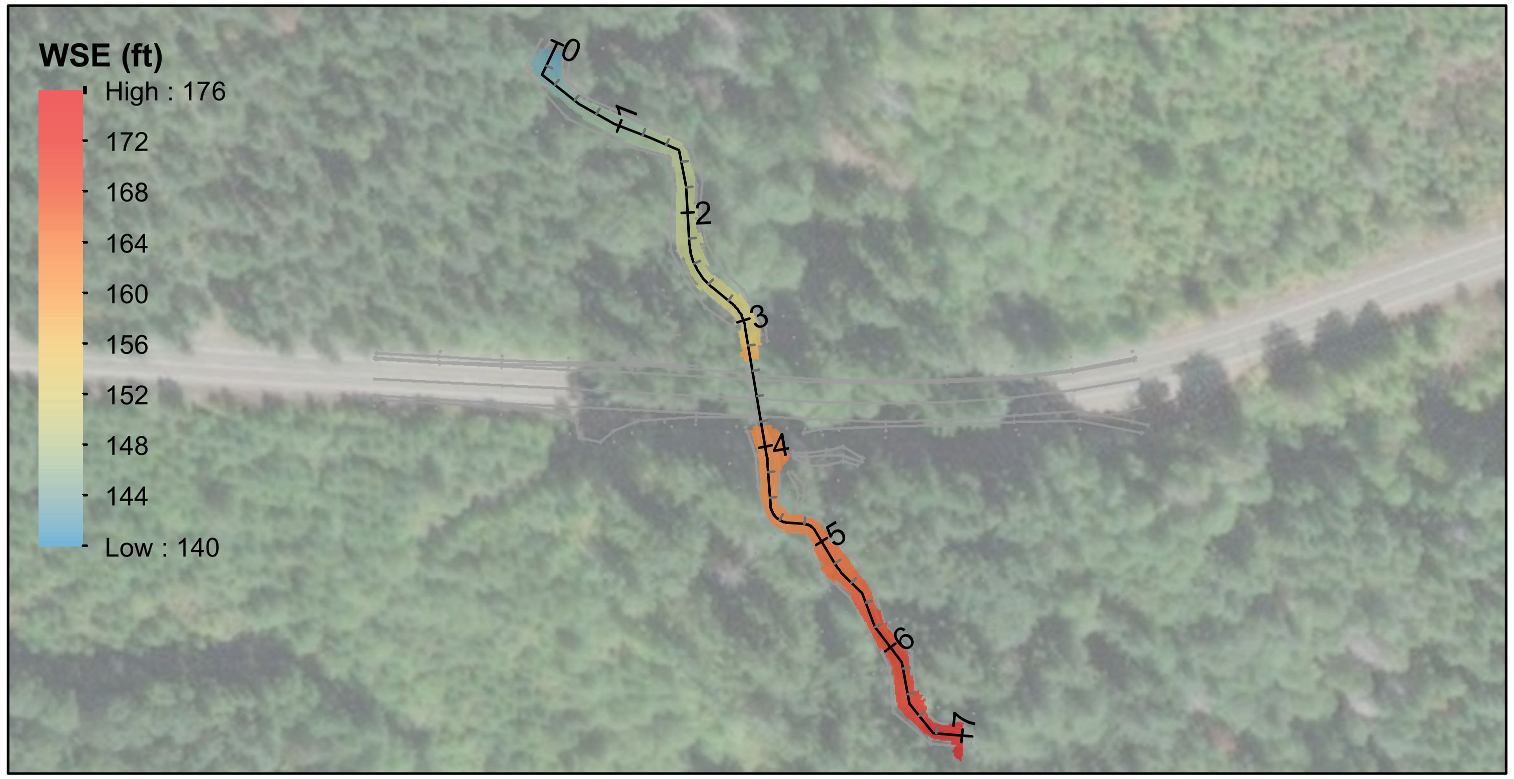
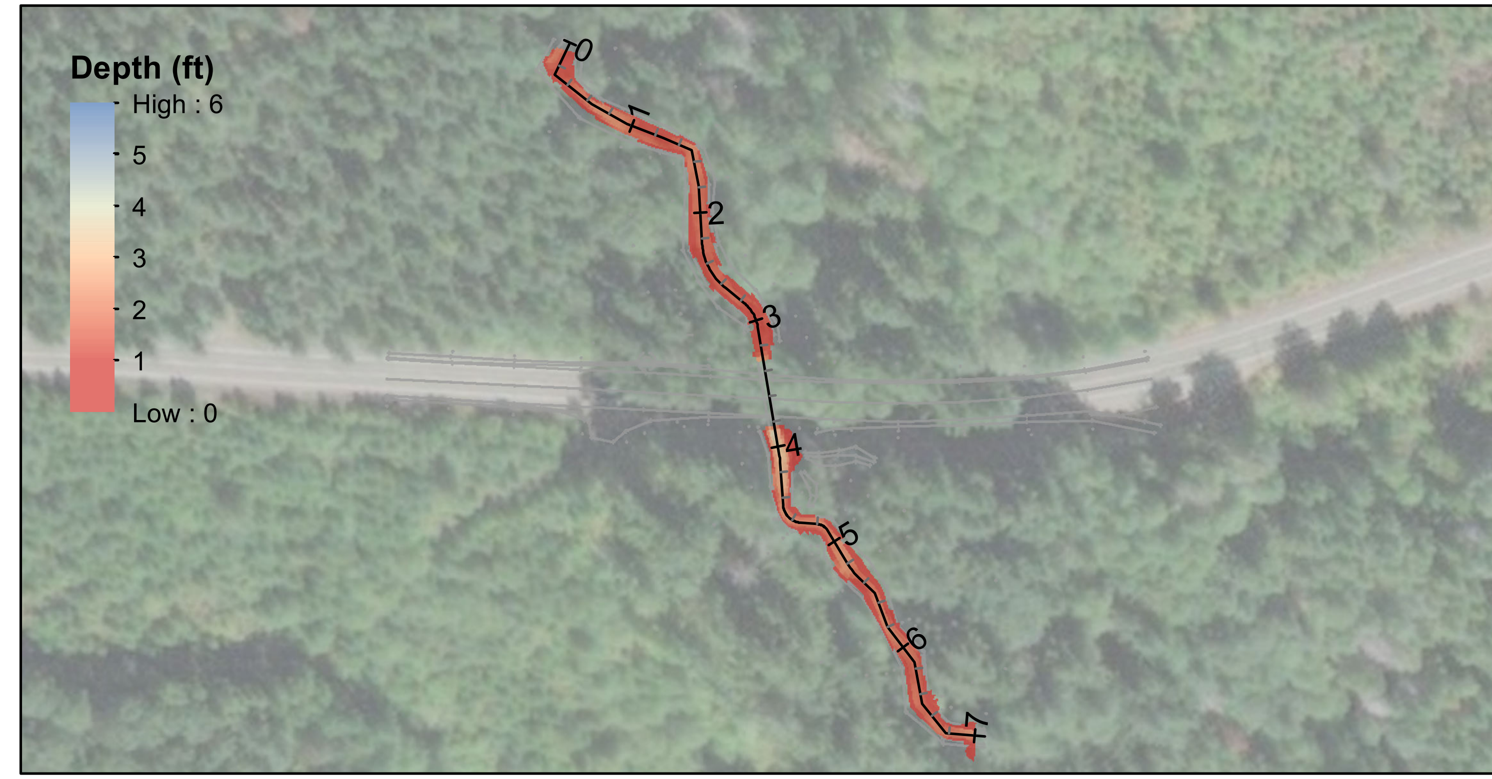
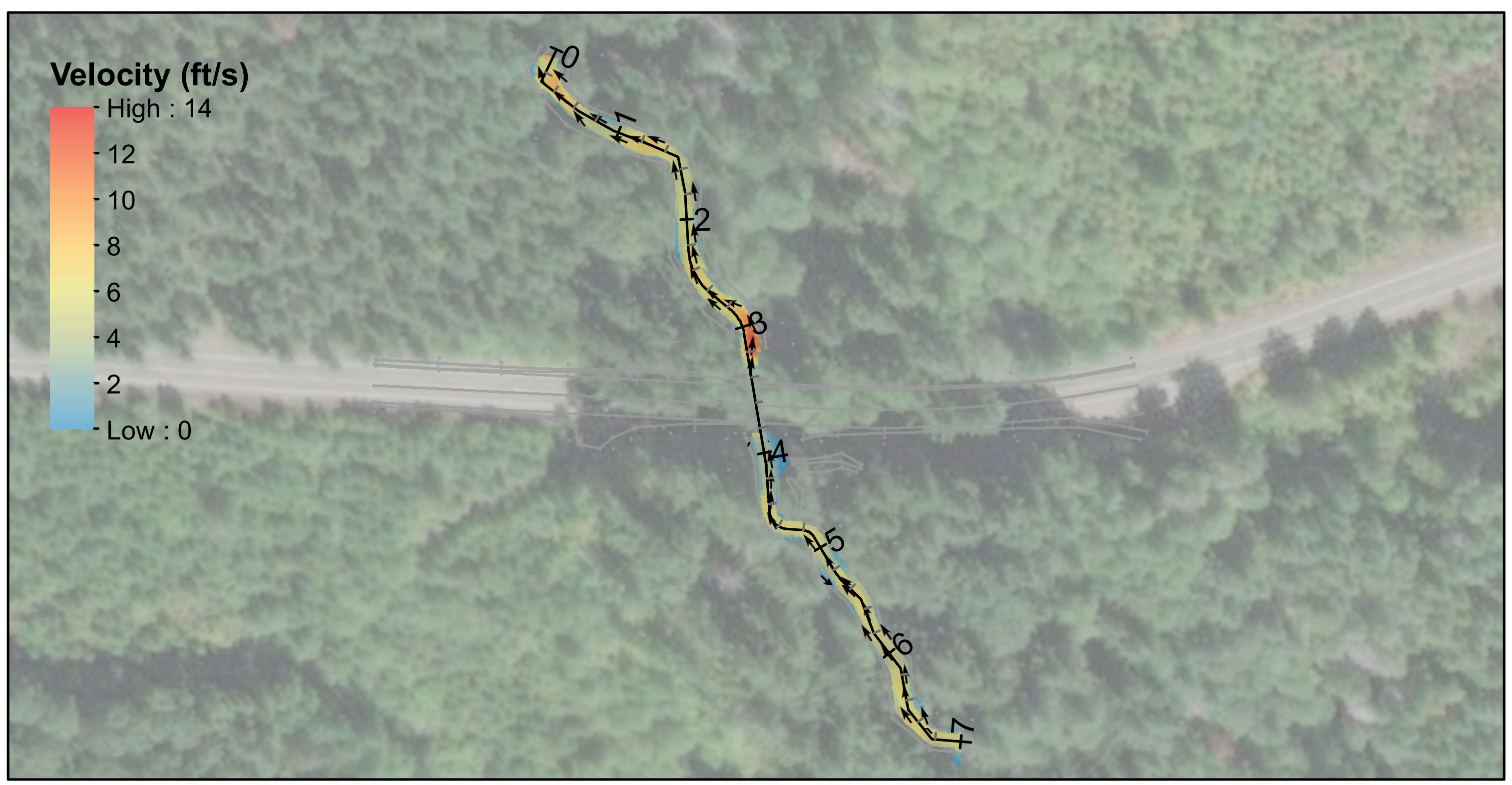


WATER SURFACE ELEVATION



DEPTH



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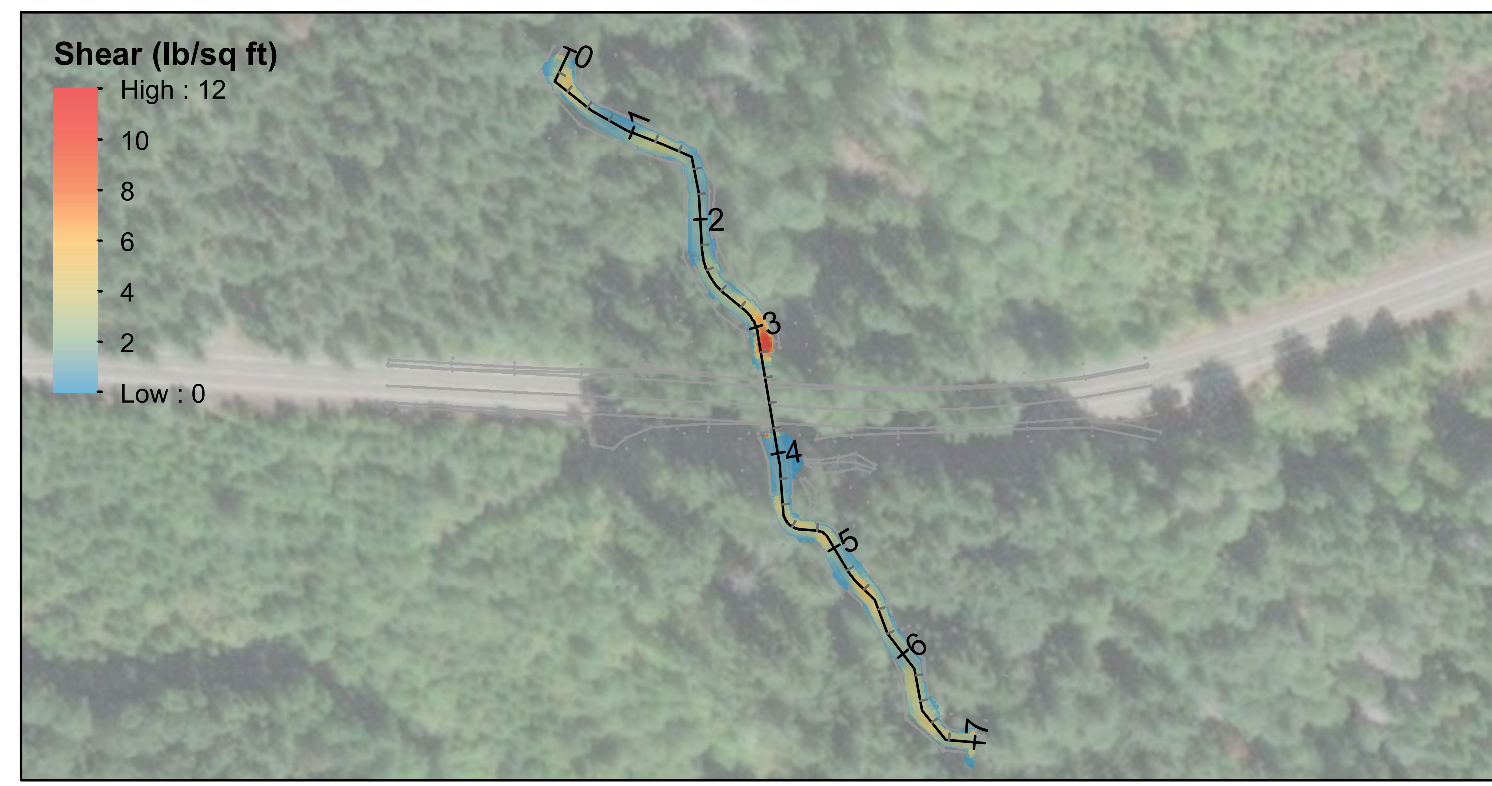


SHEAR

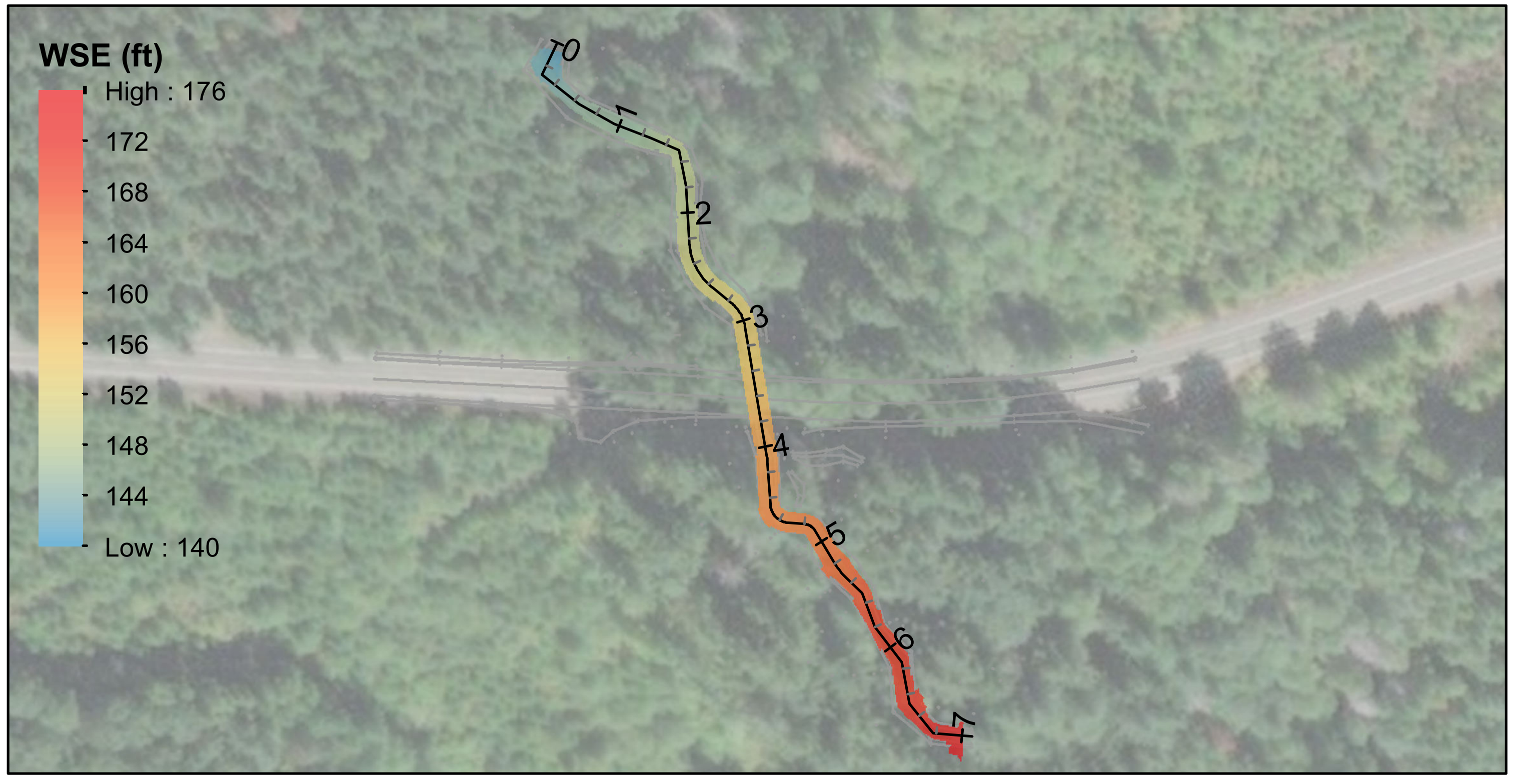
N

0 100 200 Feet

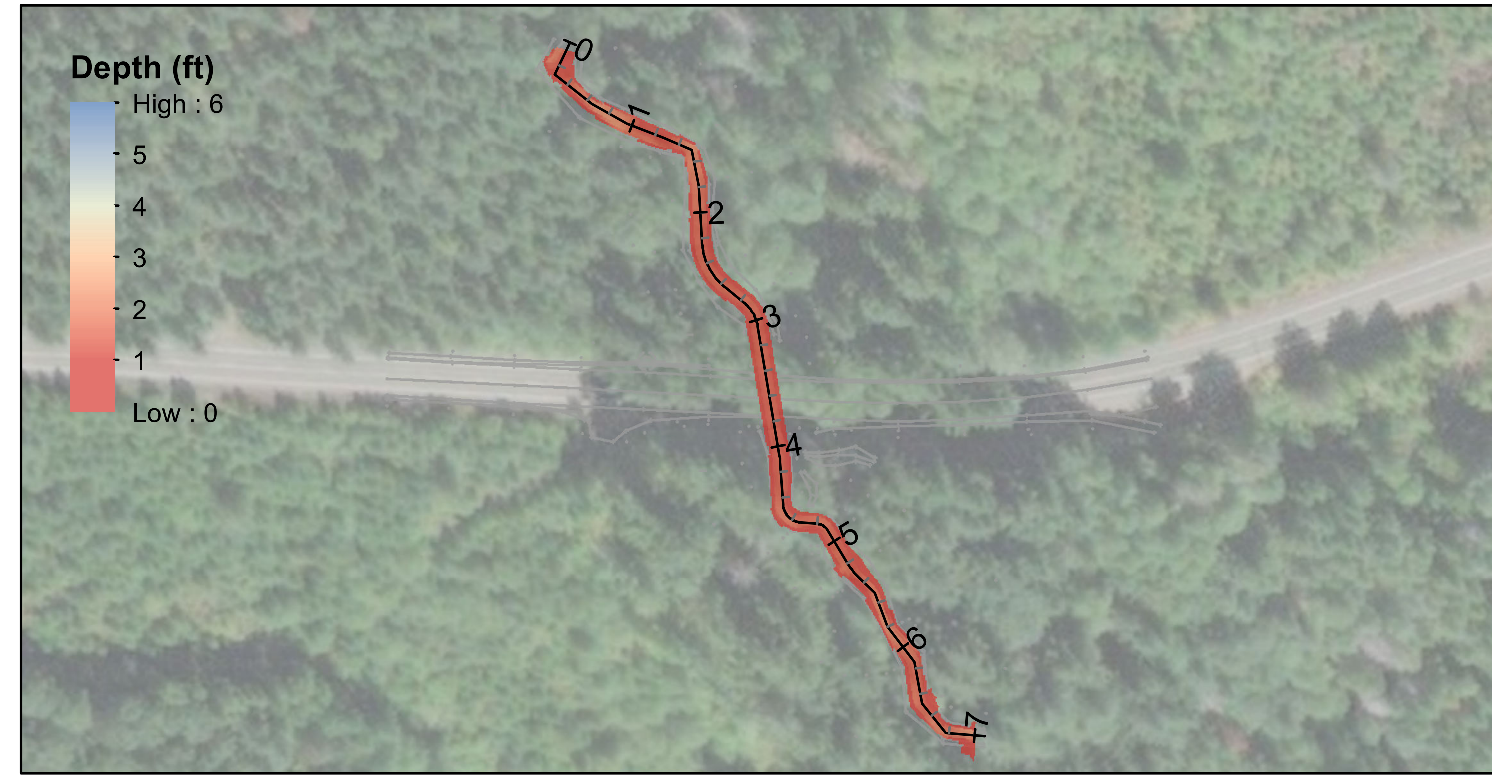
Washington State Department of Transportation

EXISTING CONDITIONS - 50 YEAR EVENT

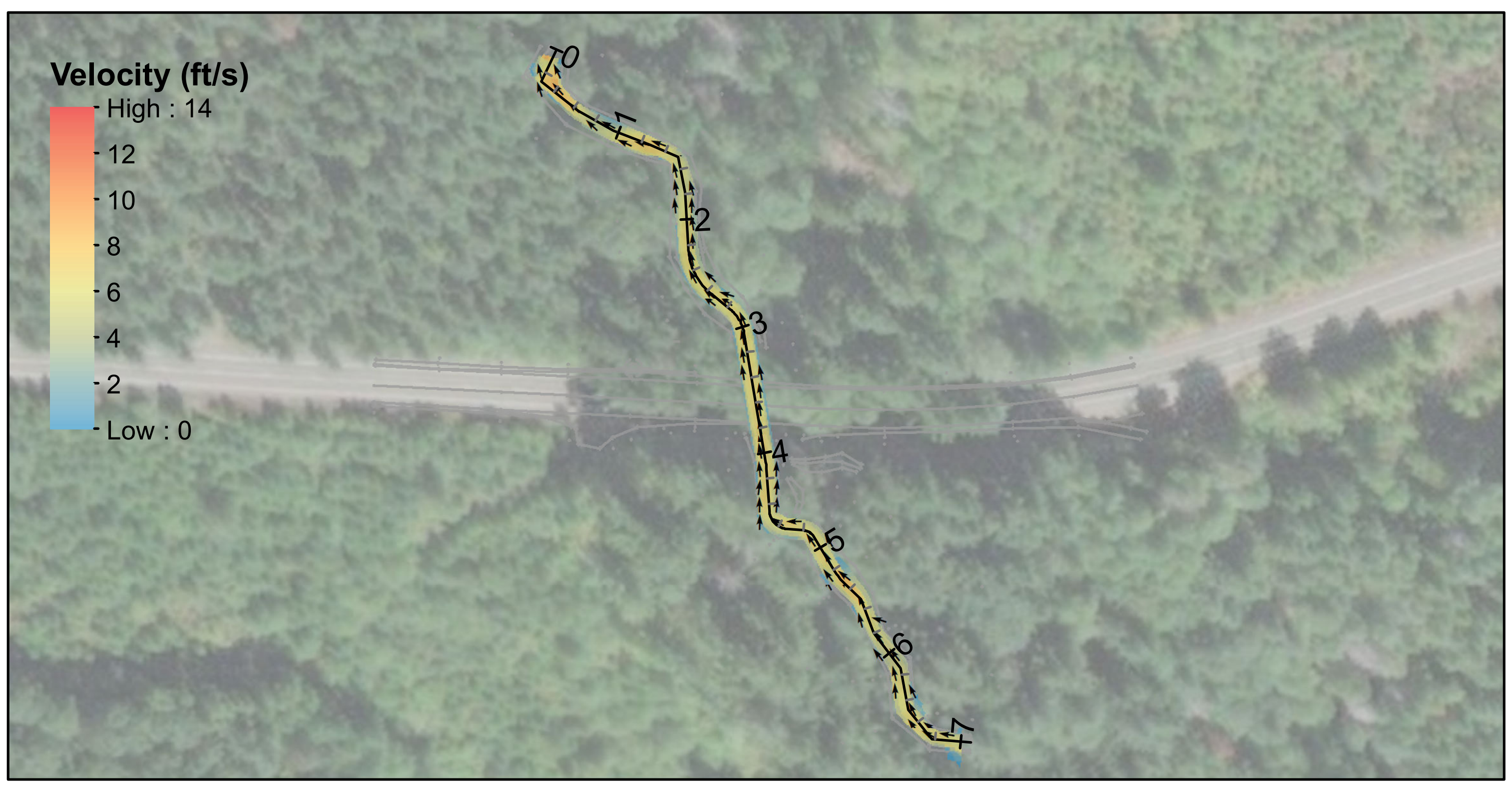
SR 108 UNNAMED TRIBUTARY TO SKOOKUM CREEK
MP 7.62



WATER SURFACE ELEVATION



DEPTH



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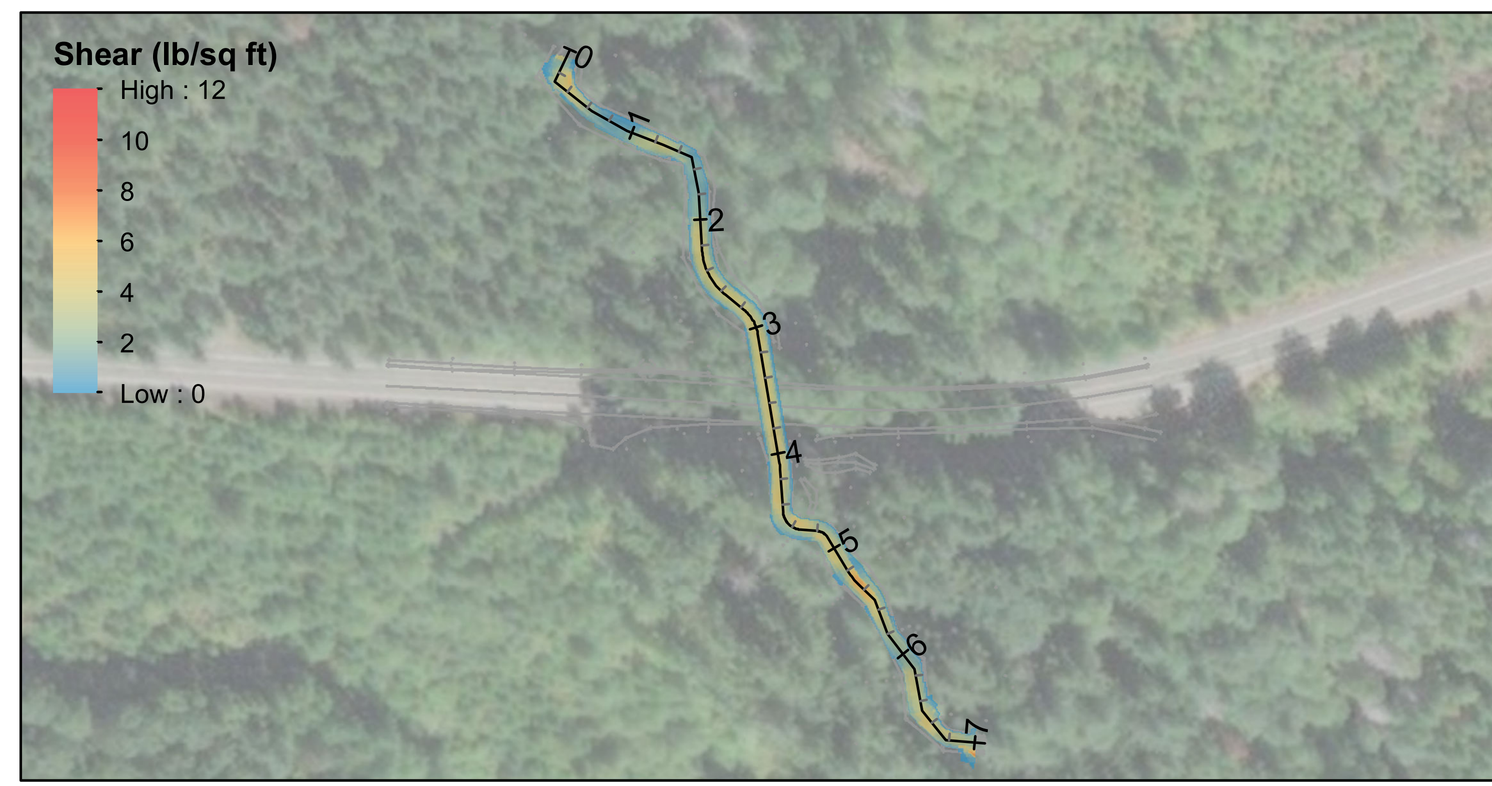

SHEAR

N

0 100 200 Feet

HDR

Washington State Department of Transportation

PROPOSED CONDITIONS - 50 YEAR EVENT

SR 108 UNNAMED TRIBUTARY TO SKOOKUM CREEK
MP 7.62

PATH: S:\SR108\MP7.62 WDFW ID 991672 UNT TO SKOOKUM\3_EX_QC_AND_PROPOSED_QC_COMMENTS_ADDRESSED\SR108_MP7.62\MODEL\RESULTS\OUTPUT FIGURES\PROPOSED_50YR FINAL.MXD - USER: DMINNER - DATE: 10/3/2019

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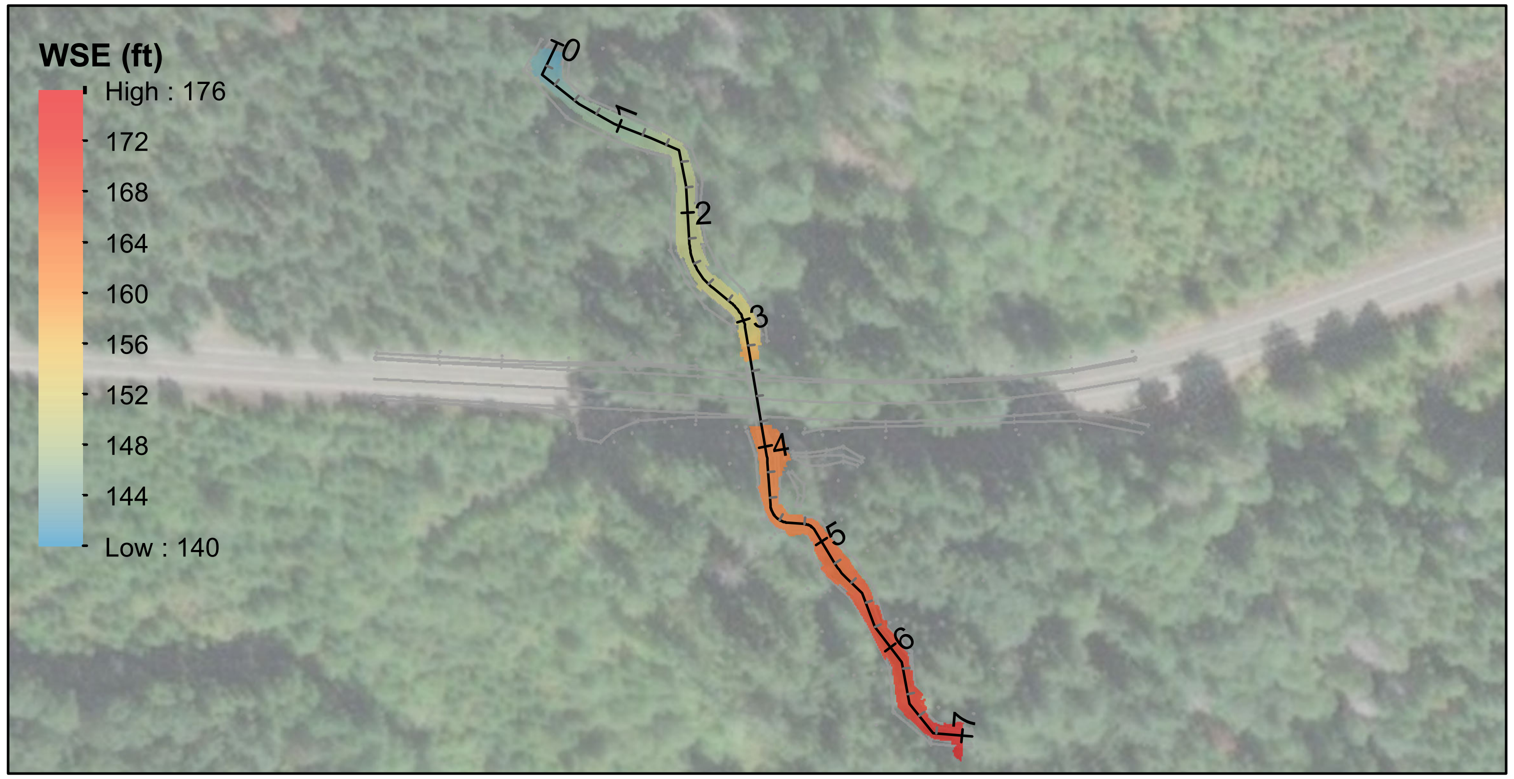
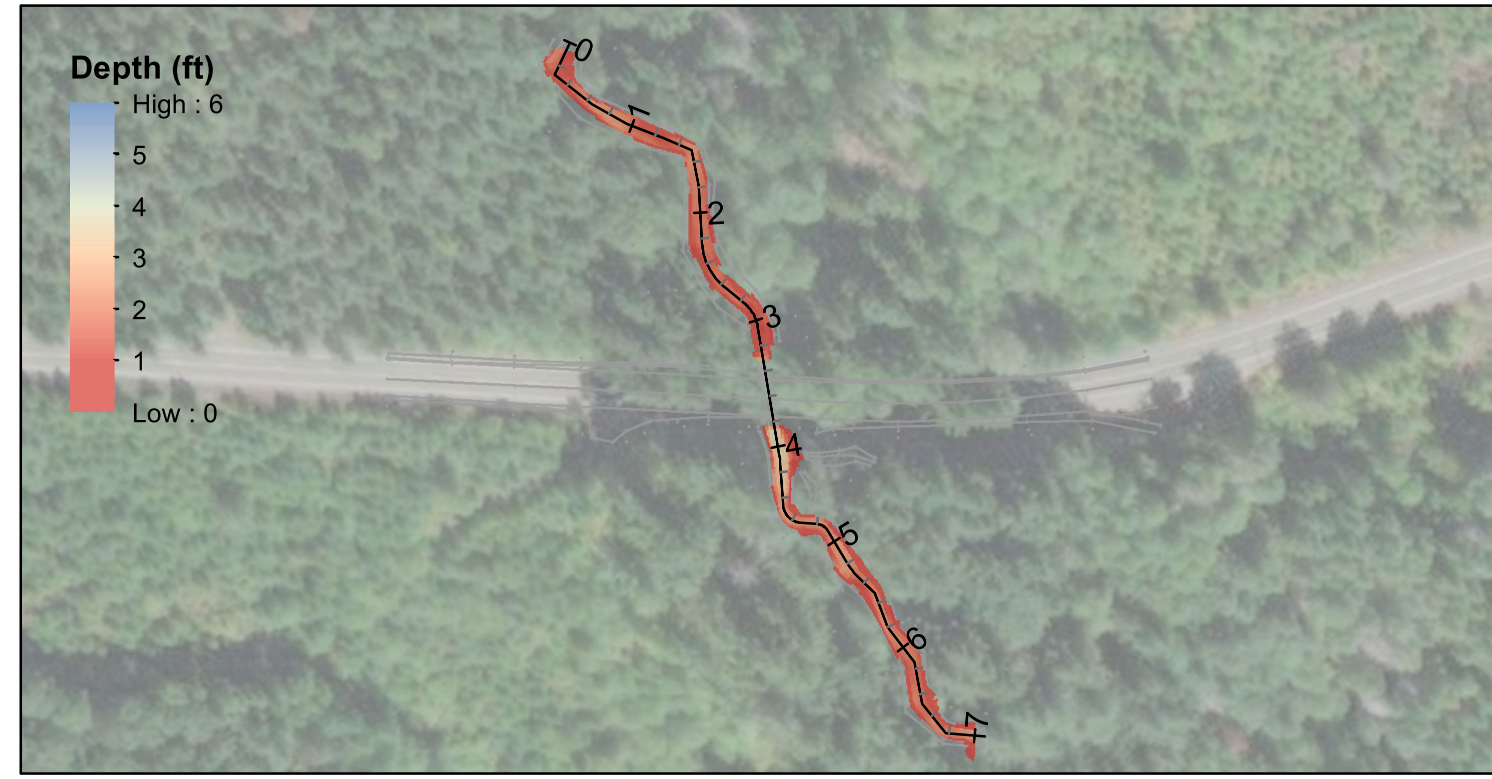
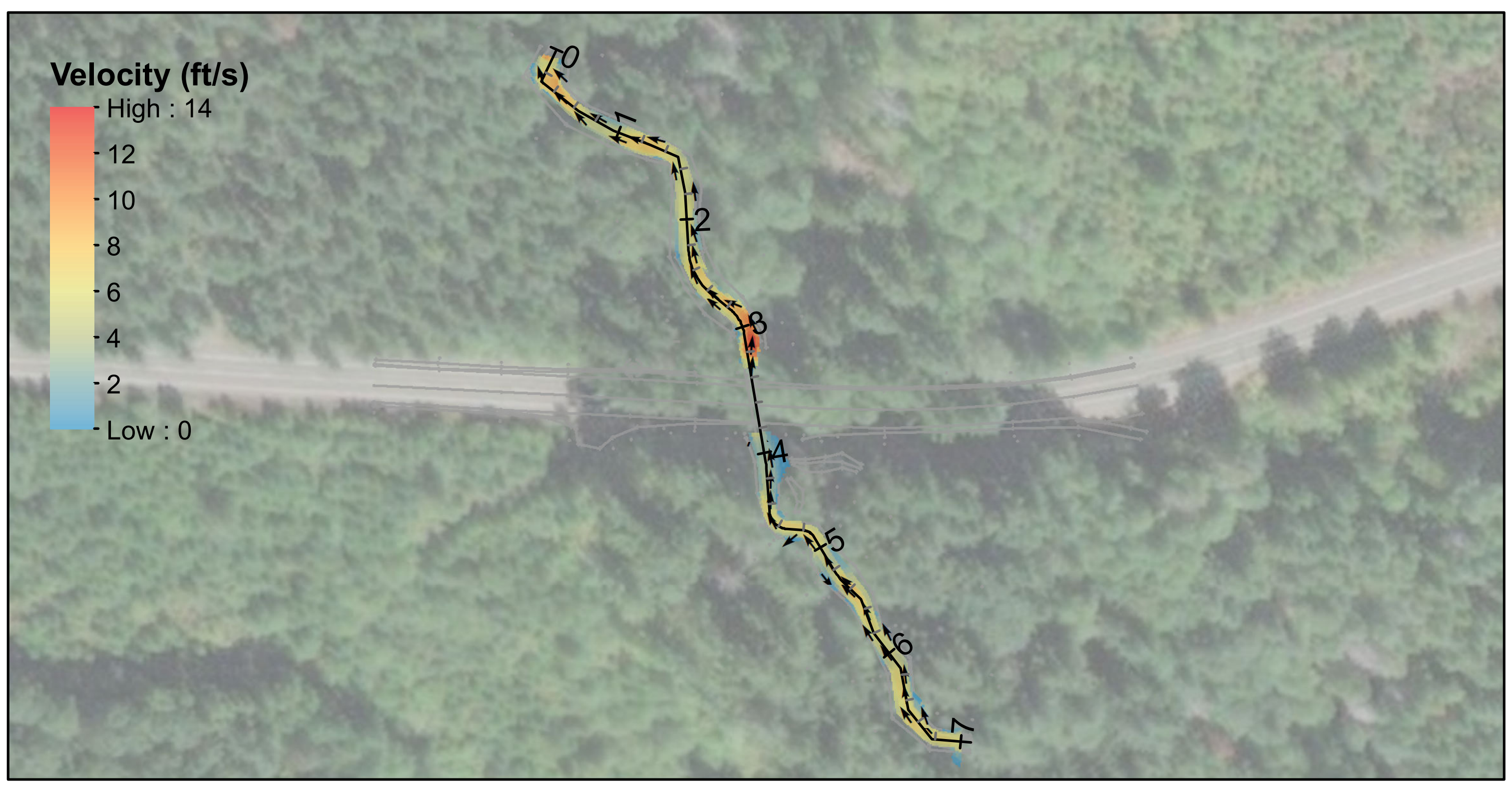


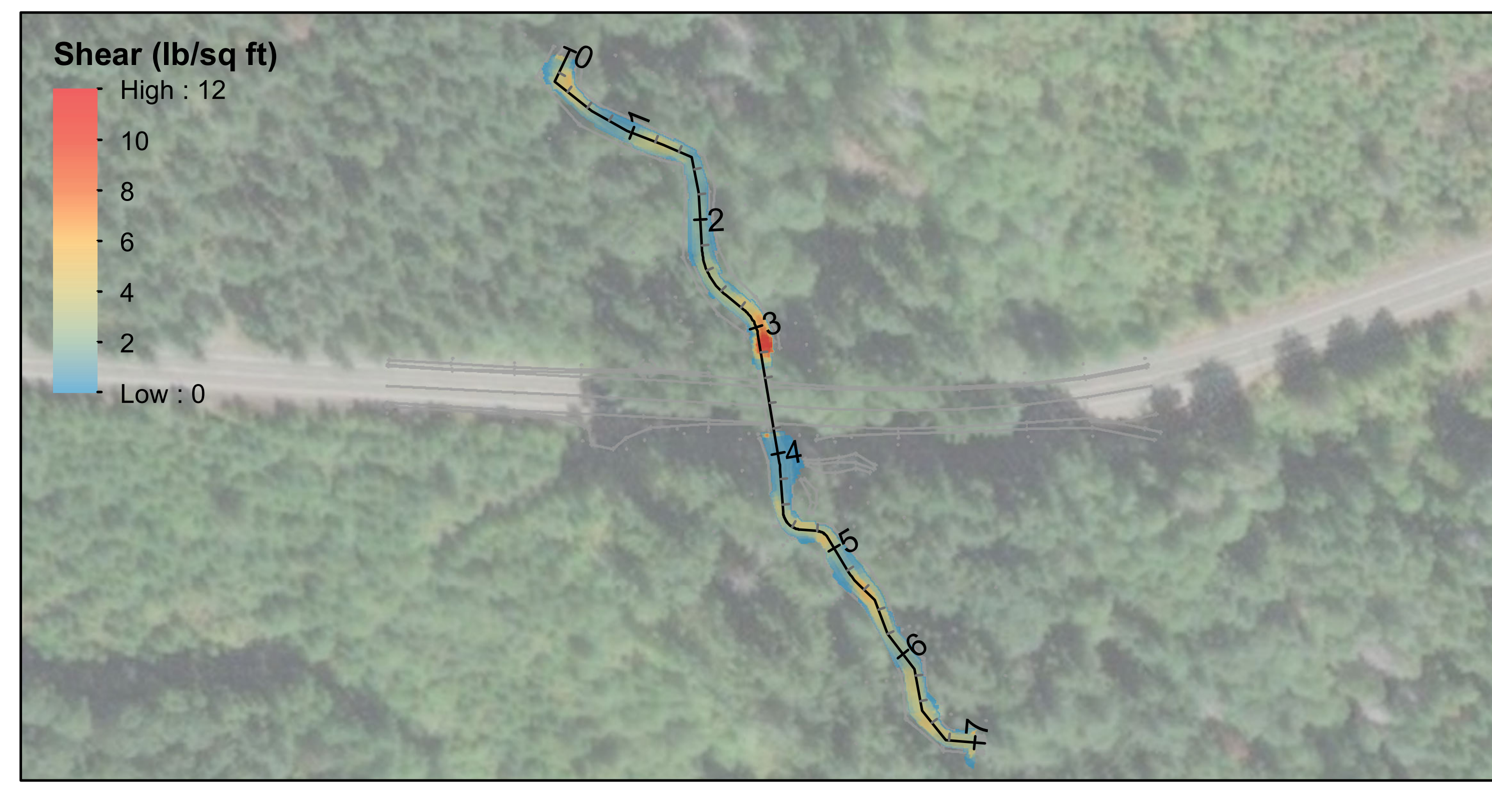
WATER SURFACE ELEVATION



DEPTH



VELOCITY



SHEAR

N

0 100 200 Feet

Washington State Department of Transportation

EXISTING CONDITIONS - 100 YEAR EVENT

SR 108 UNNAMED TRIBUTARY TO SKOOKUM CREEK
MP 7.62

PATH: S:\SR108\MP7.62 WDFW ID 991672 UNT TO SKOOKUM\3_EX_QC_AND_PROPOSED_QC_COMMENTS_ADDRESSED\SR108_MP7.62\MODEL\RESULTS\OUTPUT FIGURES\EXISTING_100YR FINAL.MXD - USER: DMINNER - DATE: 10/3/2019

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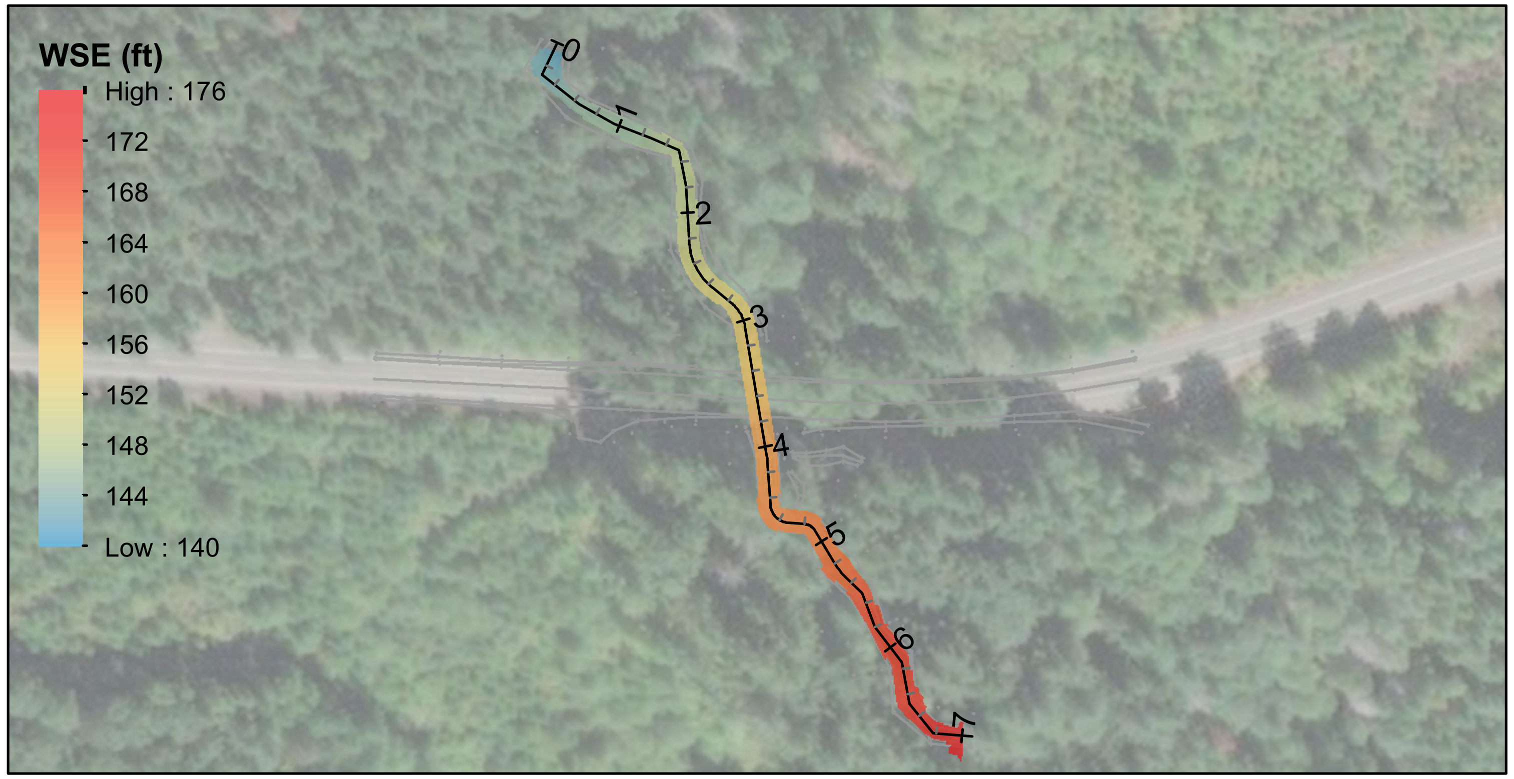
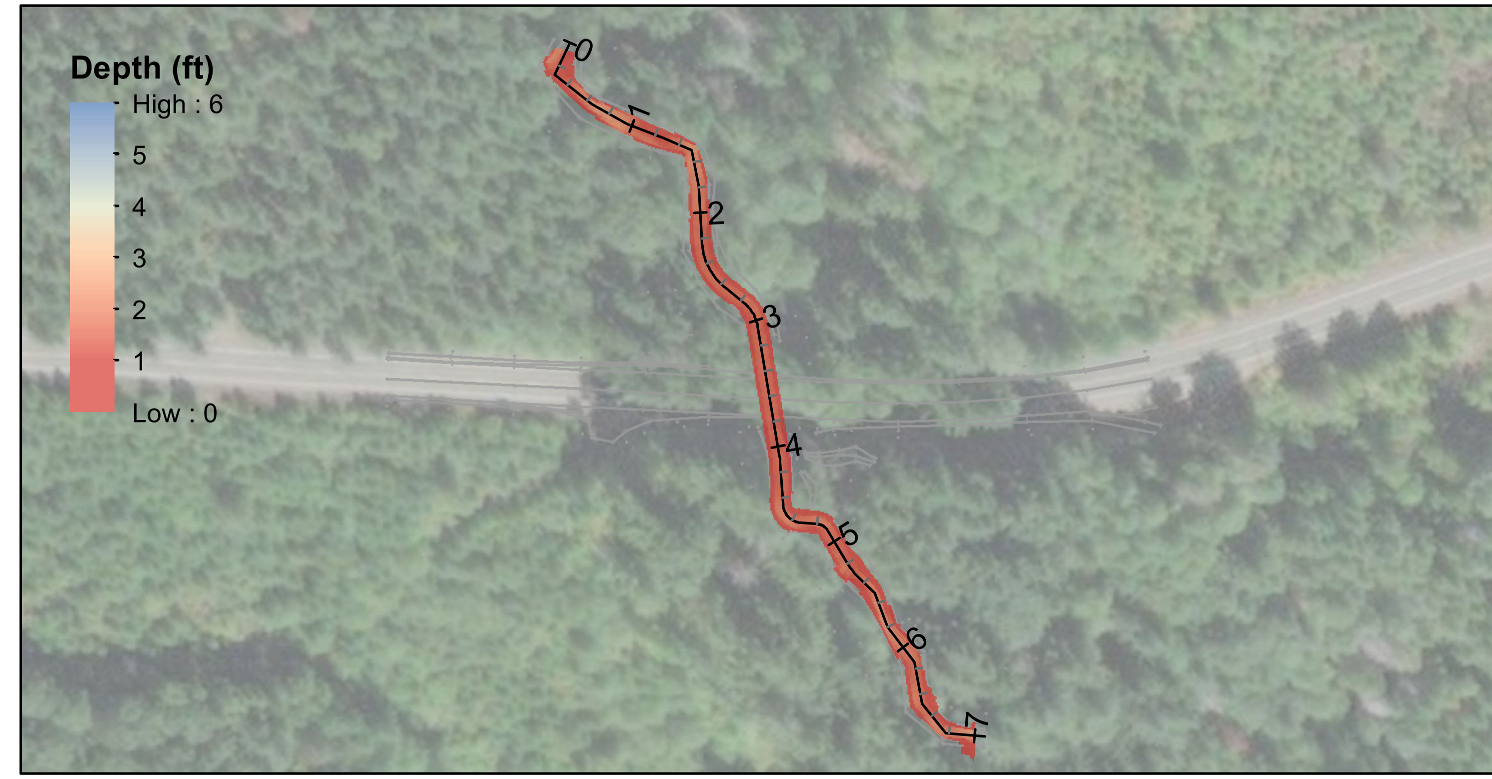
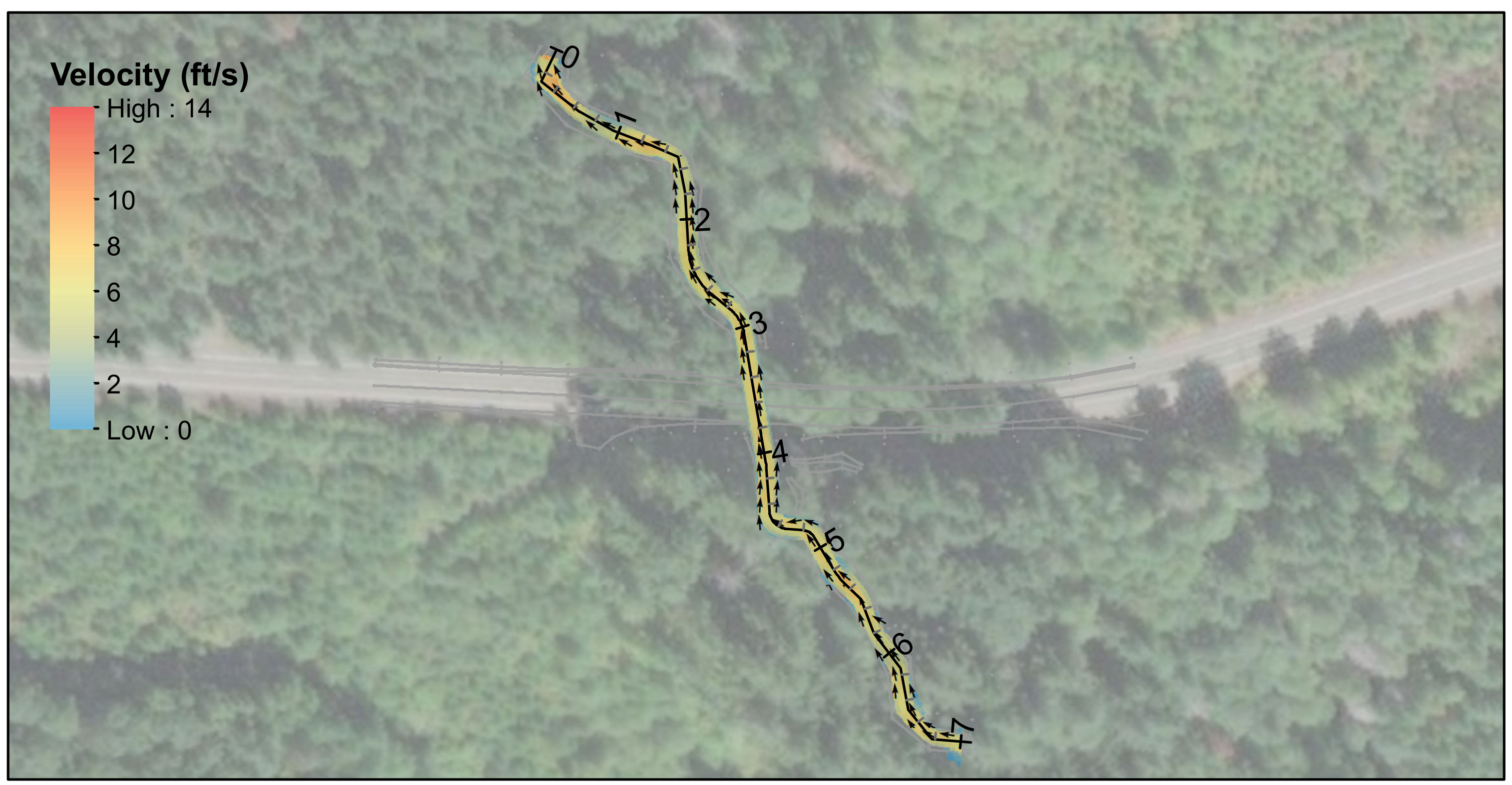


WATER SURFACE ELEVATION



DEPTH



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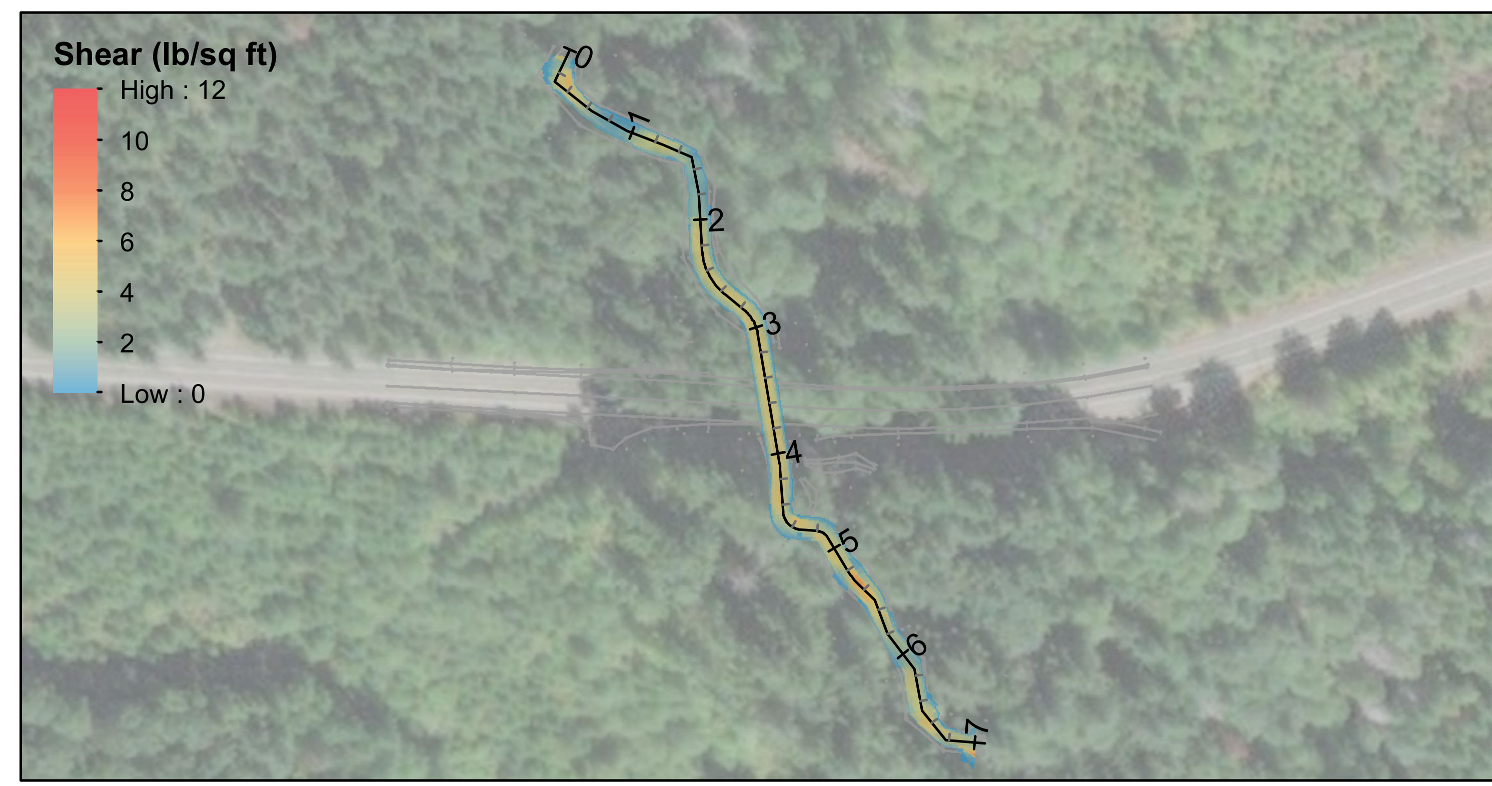


SHEAR

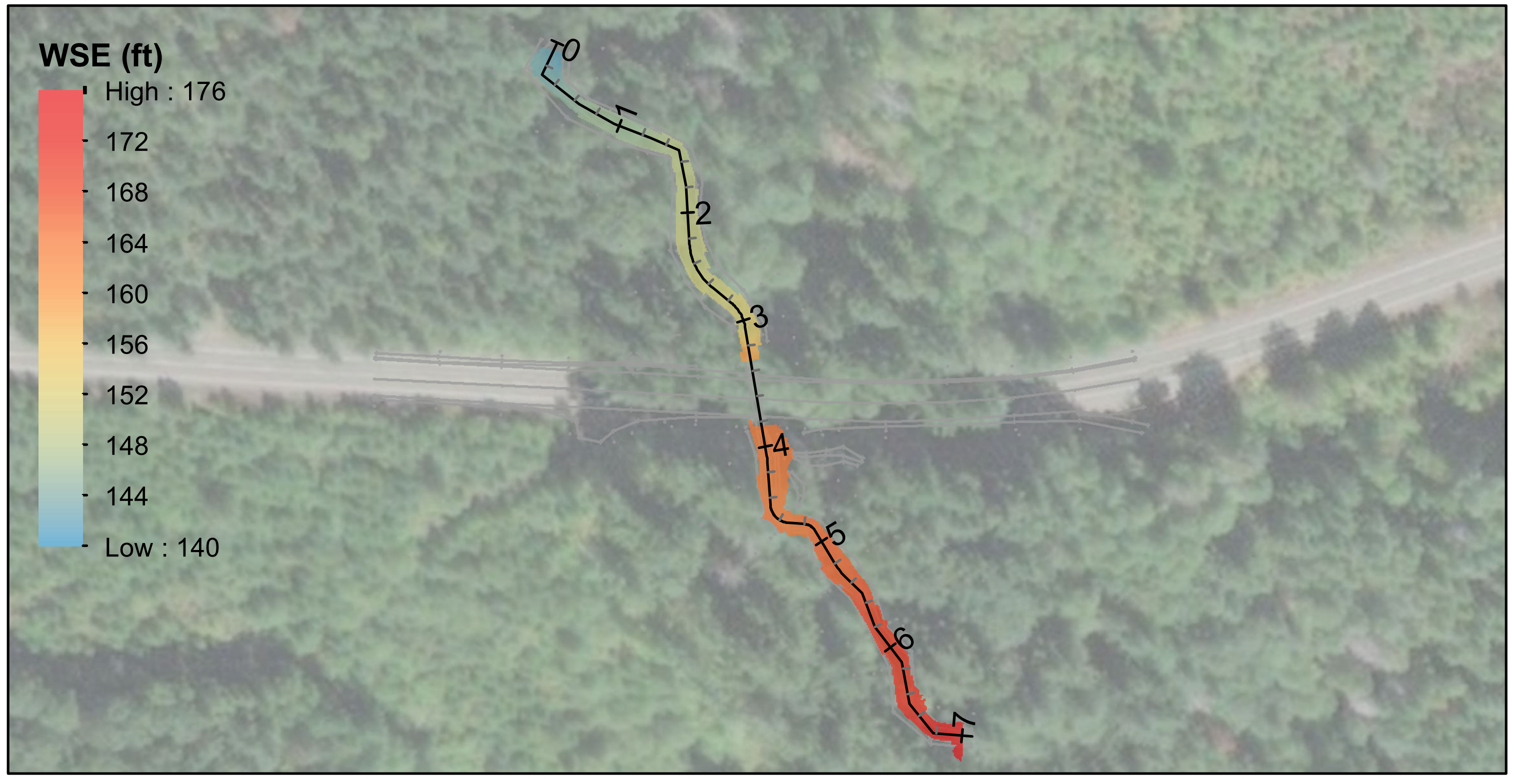
N

0 100 200 Feet

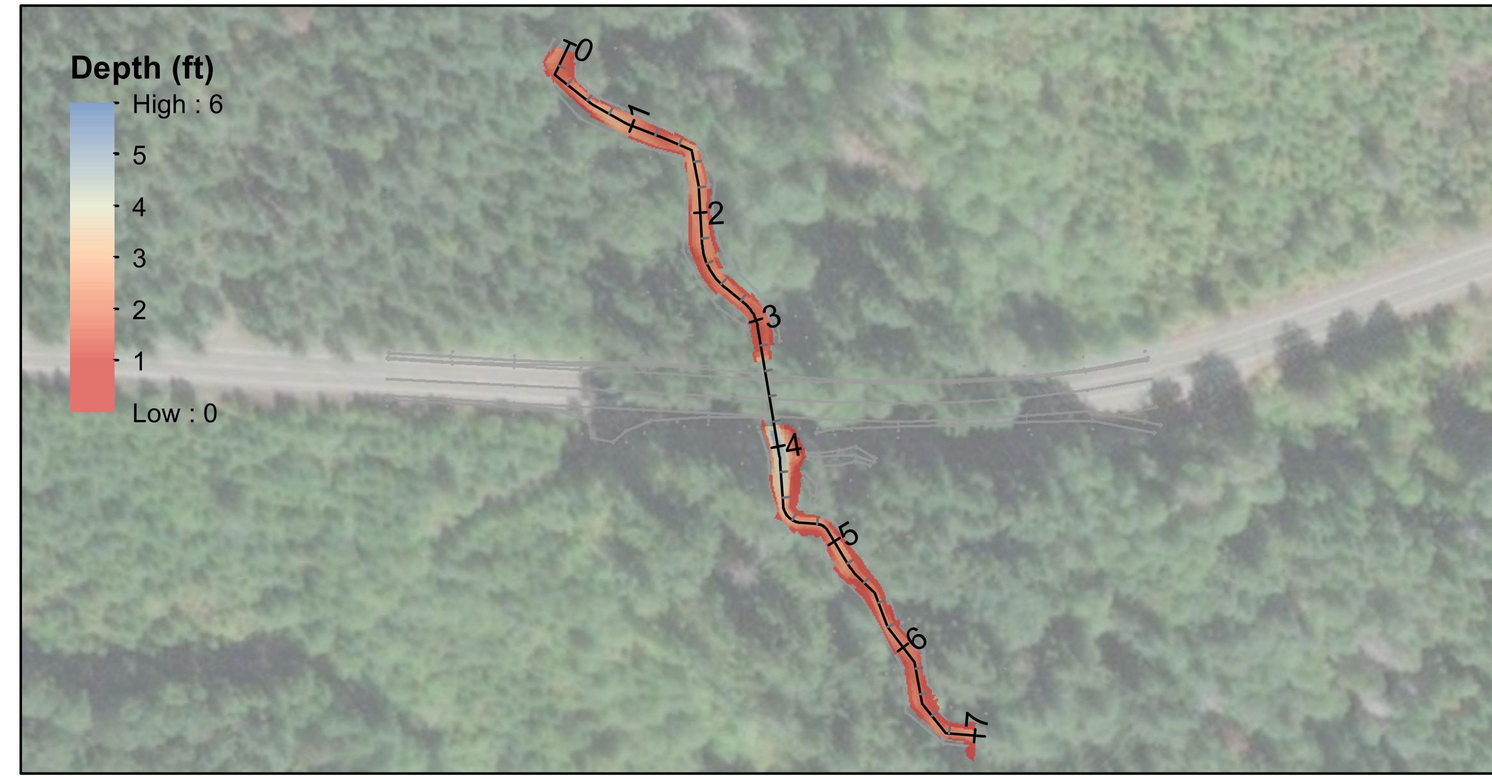
PROPOSED CONDITIONS - 100 YEAR EVENT

SR 108 UNNAMED TRIBUTARY TO SKOOKUM CREEK
MP 7.62

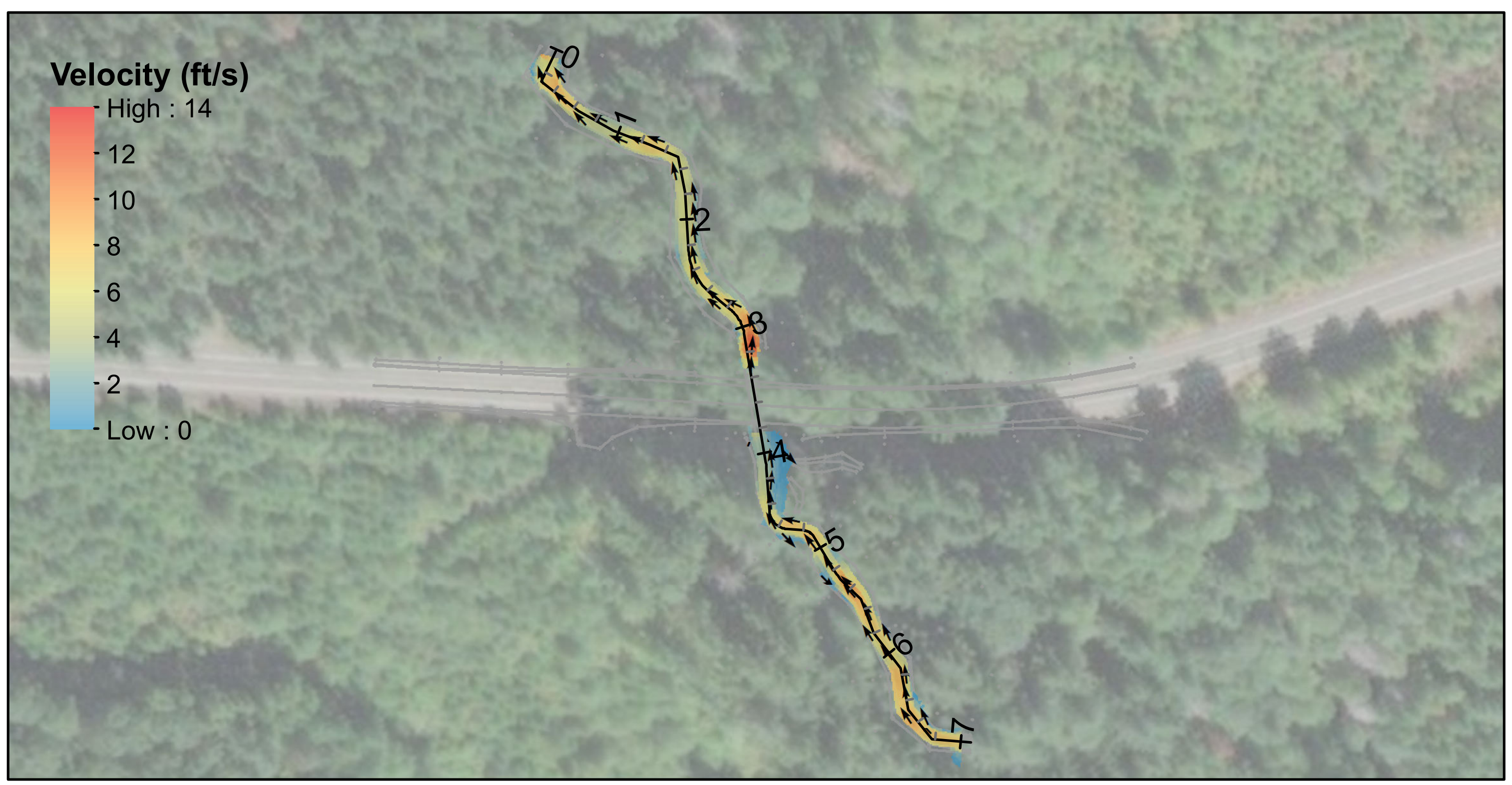
Washington State Department of Transportation



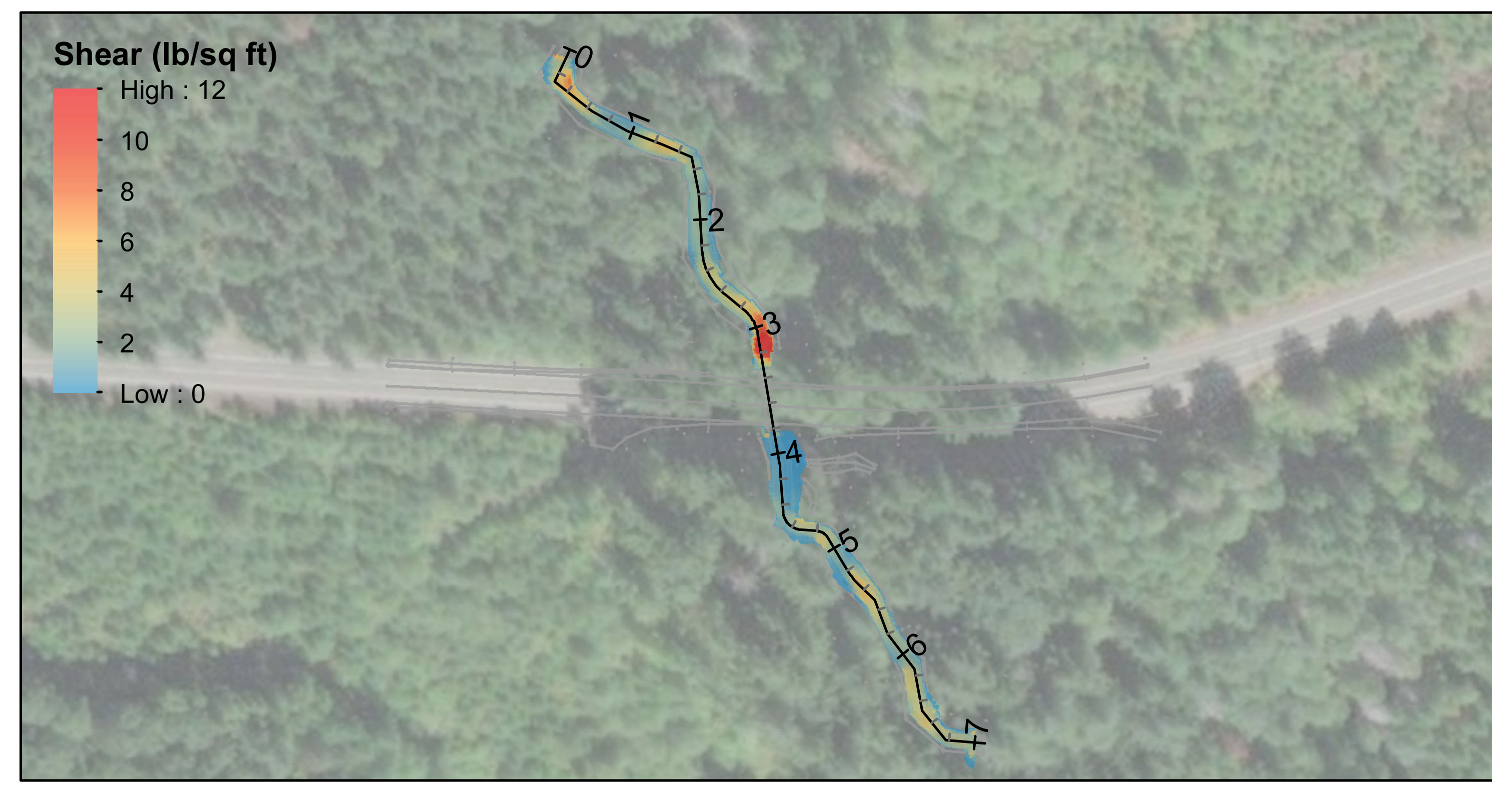
WATER SURFACE ELEVATION



DEPTH



VELOCITY



SHEAR

N

0 100 200 Feet

Washington State Department of Transportation

EXISTING CONDITIONS - 500 YEAR EVENT

SR 108 UNNAMED TRIBUTARY TO SKOOKUM CREEK
MP 7.62

PATH: S:\SR108\MP7.62 WDFW ID 991672 UNT TO SKOOKUM\3_EX_QC_AND_PROPOSED_QC_COMMENTS_ADDRESSED\SR108_MP7.62\MODEL\RESULTS\OUTPUT FIGURES\EXISTING_500YR FINAL.MXD - USER: DMINNER - DATE: 10/3/2019

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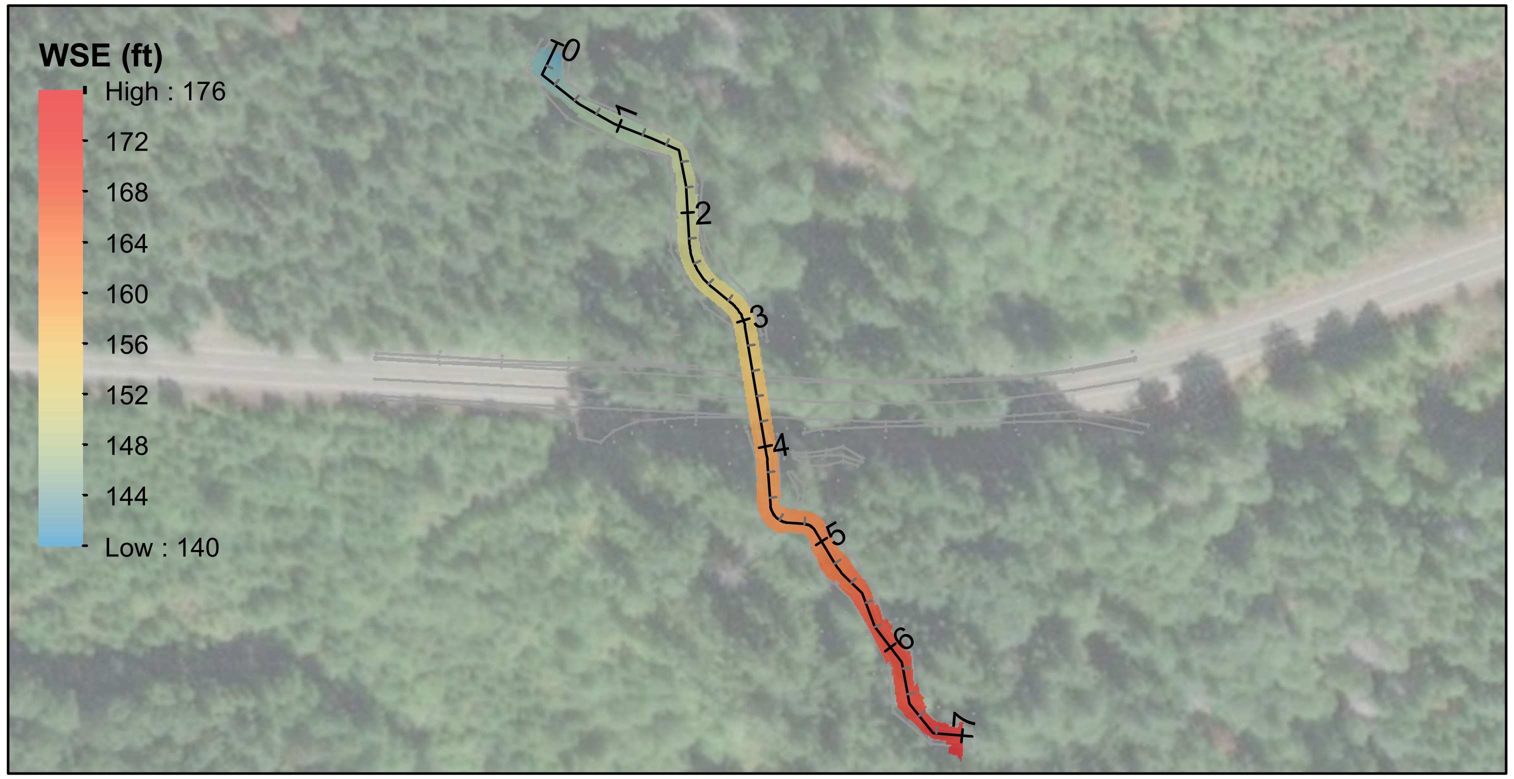
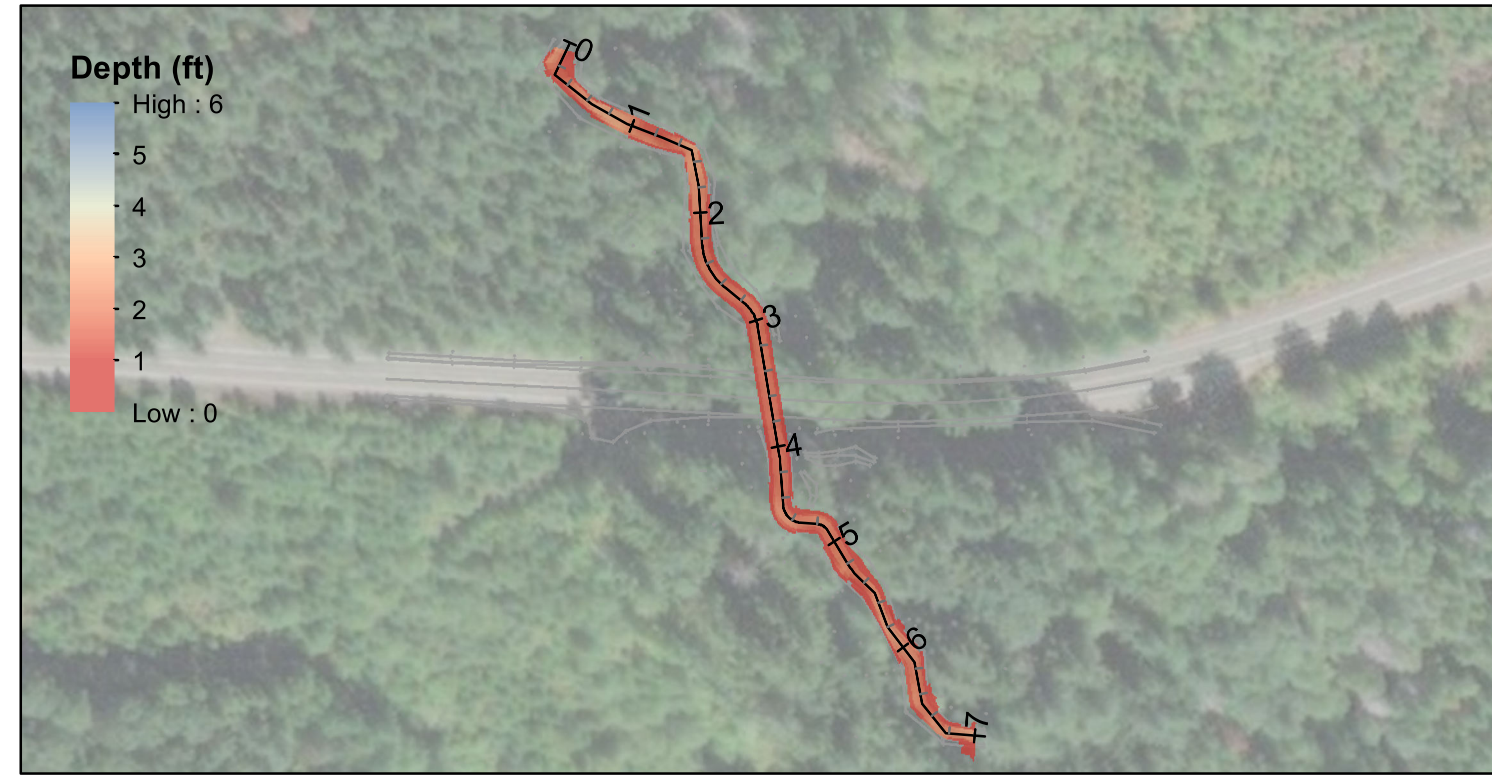
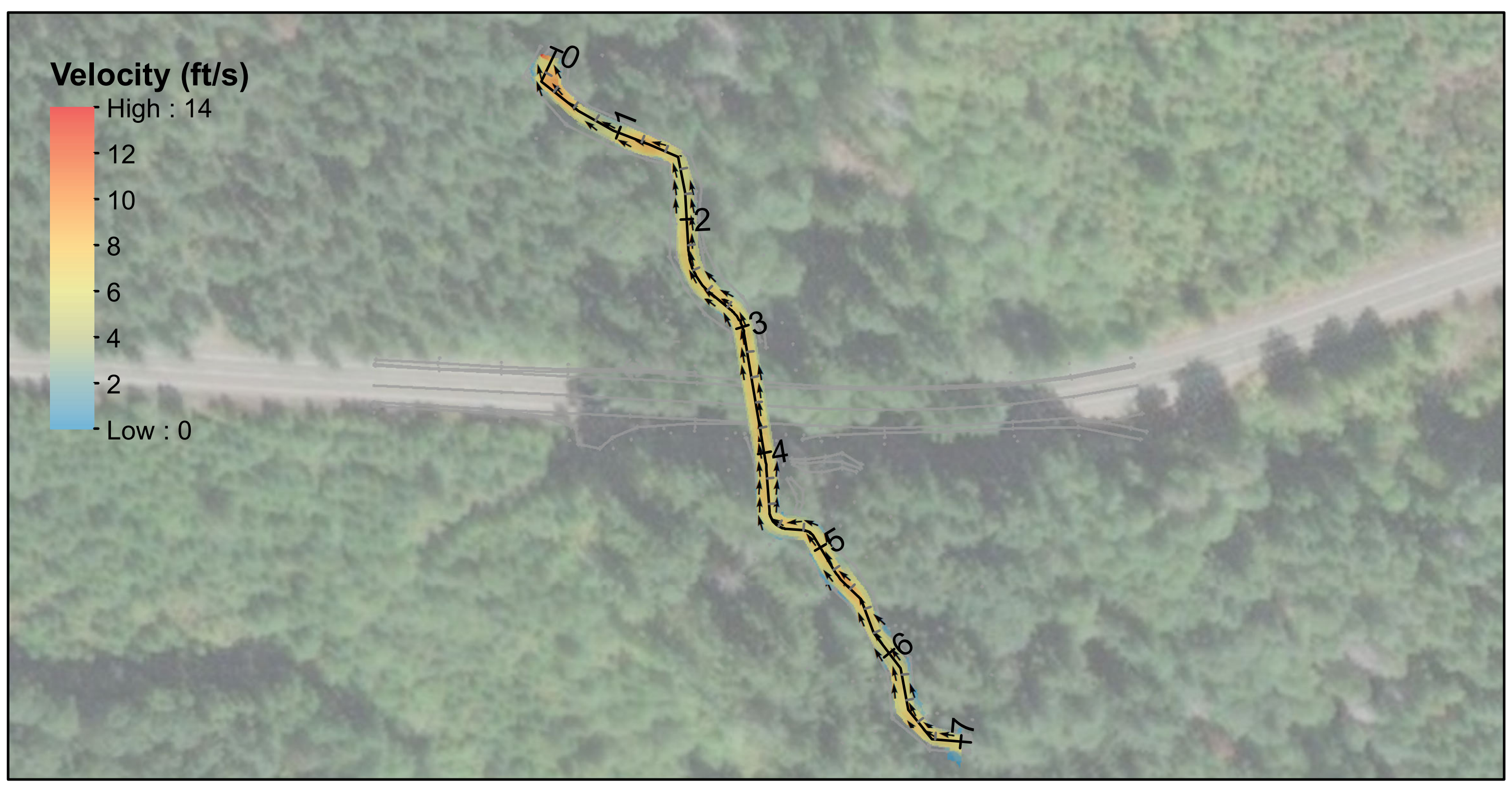


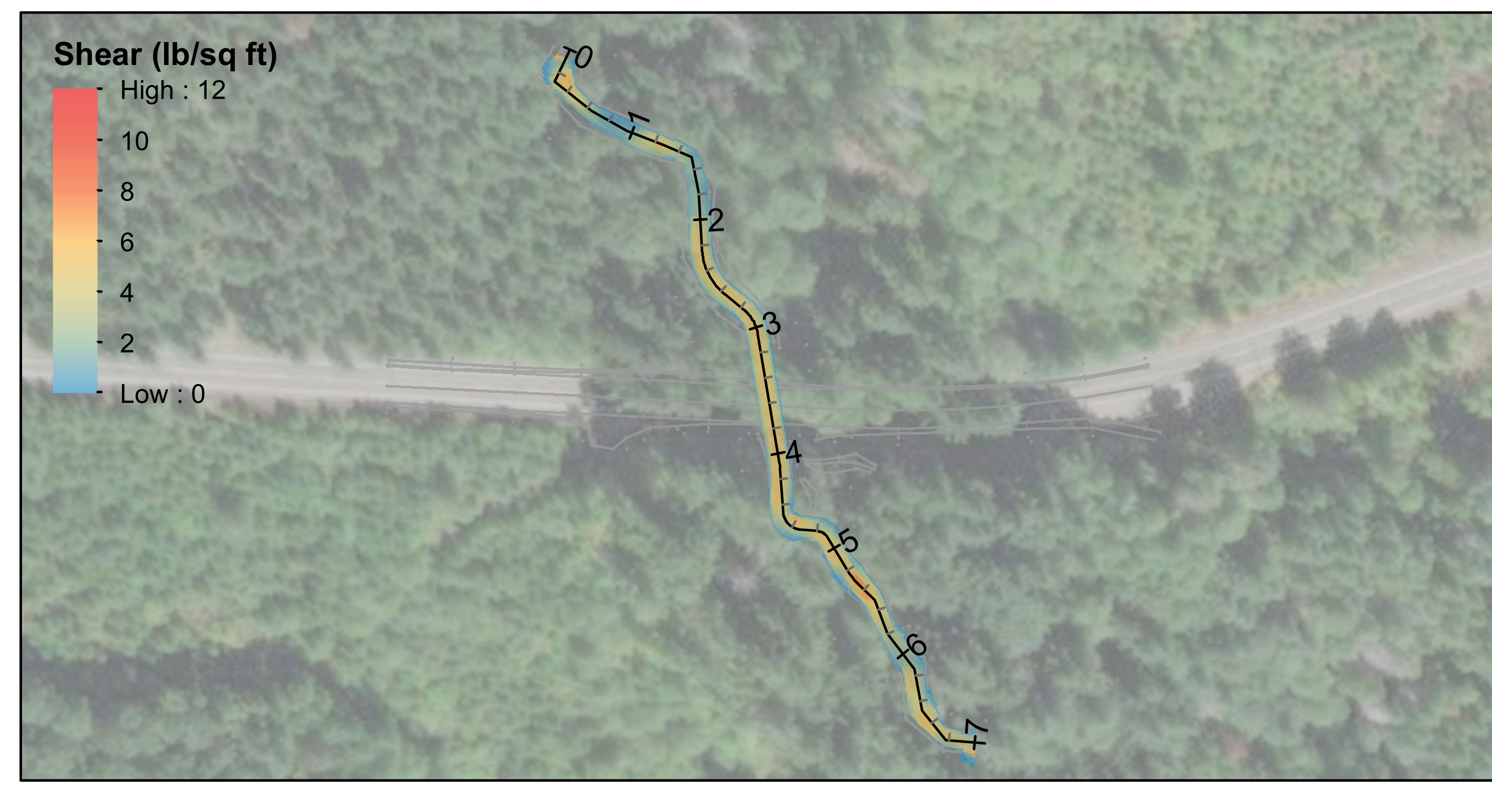
WATER SURFACE ELEVATION



DEPTH



VELOCITY



SHEAR

N

0 100 200 Feet

Washington State
Department of Transportation

PROPOSED CONDITIONS - 500 YEAR EVENT

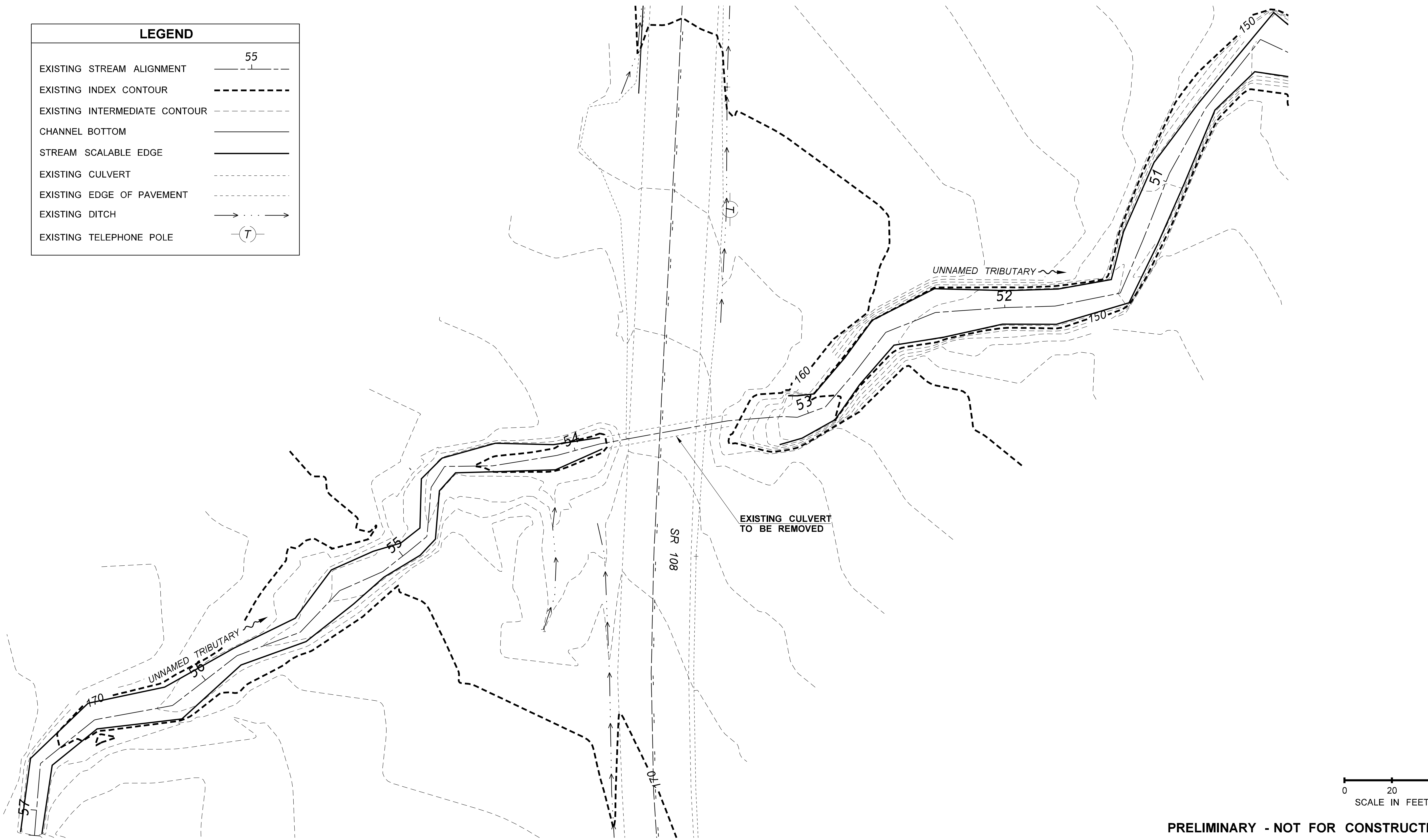
SR 108 UNNAMED TRIBUTARY TO SKOOKUM CREEK
MP 7.62

Appendix B – Stream Plan Sheets, Profile, Details

T.19N. R.4W. W.M.

LEGEND

EXISTING STREAM ALIGNMENT	55
EXISTING INDEX CONTOUR	
EXISTING INTERMEDIATE CONTOUR	
CHANNEL BOTTOM	
STREAM SCALABLE EDGE	
EXISTING CULVERT	
EXISTING EDGE OF PAVEMENT	
EXISTING DITCH	
EXISTING TELEPHONE POLE	T



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PLOTTED BY	CWILCOX			
DESIGNED BY	S. BEVAN			
ENTERED BY	C. WILCOX			
CHECKED BY	J. HEILMAN			
PROJ. ENGR.	J. METTLER			
REGIONAL ADM.	J. WYNANDS	REVISION	DATE	BY

REGION NO. 10	STATE WASH	FED.AID PROJ.NO.
JOB NUMBER XXXXX		
CONTRACT NO.		LOCATION NO. XL5950

P.E. STAMP BOX DATE

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MP 7.62
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EXISTING STREAM PLAN

PLAN REF NO CE1

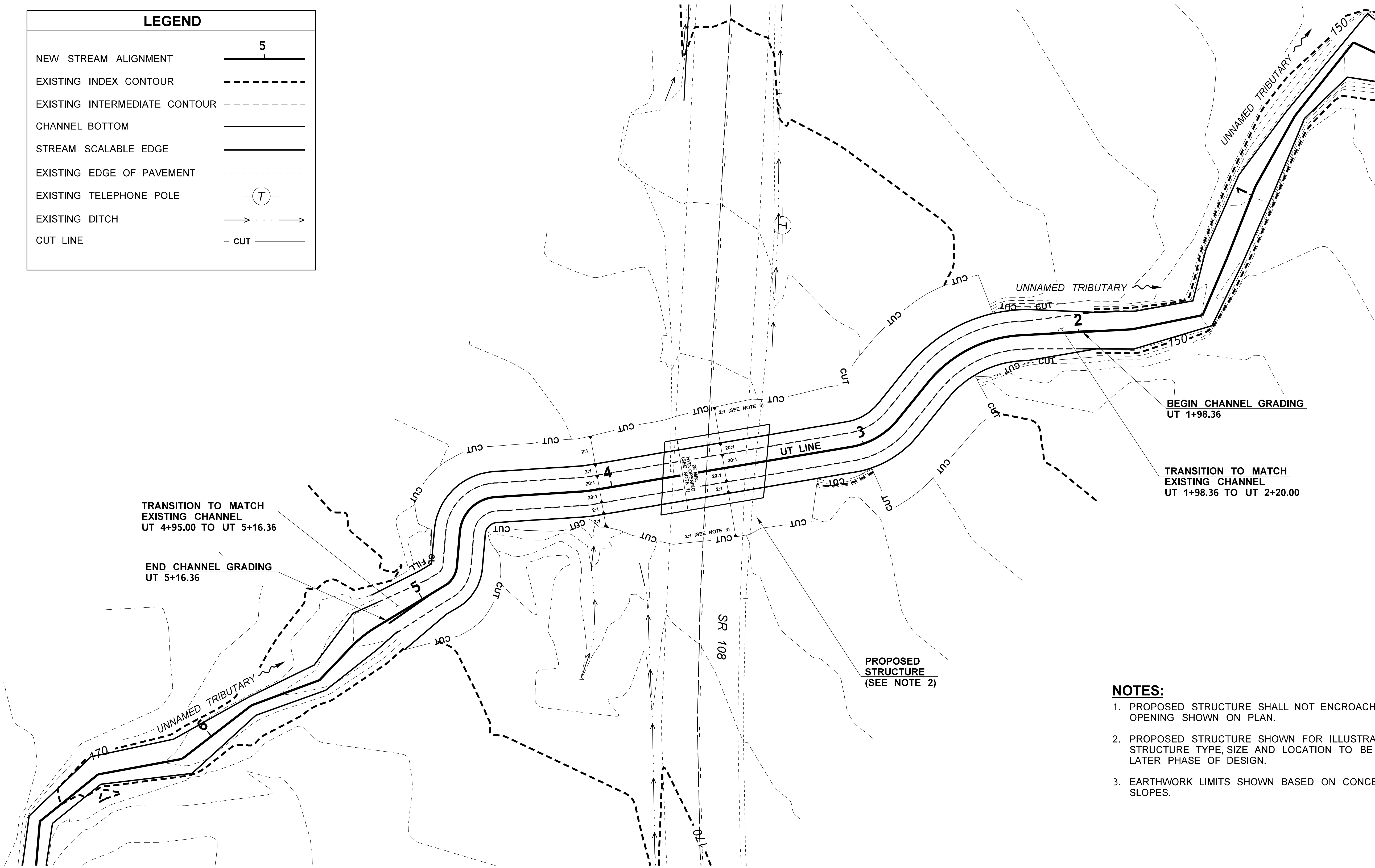
SHEET 1 OF 4 SHEETS

pw:\\HQOLYMAPPPW03P.WSDOT.LOC:WSDOT\Documents_HQ\Fish Passage\ORproj\108\7.62_TribToSkookumCr2\Hydraulics_CAD_Sheets\StreamPlanProfDetails\XL5950_PS_CE_001

T.19N. R.4W. W.M.

LEGEND

NEW STREAM ALIGNMENT	5
EXISTING INDEX CONTOUR	
EXISTING INTERMEDIATE CONTOUR	
CHANNEL BOTTOM	
STREAM SCALABLE EDGE	
EXISTING EDGE OF PAVEMENT	
EXISTING TELEPHONE POLE	T
EXISTING DITCH	
CUT LINE	CUT



NOTES:

1. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO HYDRAULIC OPENING SHOWN ON PLAN.
2. PROPOSED STRUCTURE SHOWN FOR ILLUSTRATIVE PURPOSES ONLY. STRUCTURE TYPE, SIZE AND LOCATION TO BE DETERMINED DURING LATER PHASE OF DESIGN.
3. EARTHWORK LIMITS SHOWN BASED ON CONCEPTUAL DAYLIGHT SLOPES.

0 20 40
SCALE IN FEET

PRELIMINARY - NOT FOR CONSTRUCTION

FILE NAME	c:\pwworking\pw_wsdot\d0249824\XL5950_PS_CR_001.dgn
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DATE	5/20/2020
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DESIGNED BY	S. BEVAN
ENTERED BY	C. WILCOX
CHECKED BY	J. HEILMAN
PROJ. ENGR.	J. METTLER
REGIONAL ADM.	J. WYNANDS

REVISION | DATE | BY

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	
JOB NUMBER XXXXX		
CONTRACT NO.	LOCATION NO. XL5950	

P.E. STAMP BOX DATE

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STREAM PLAN

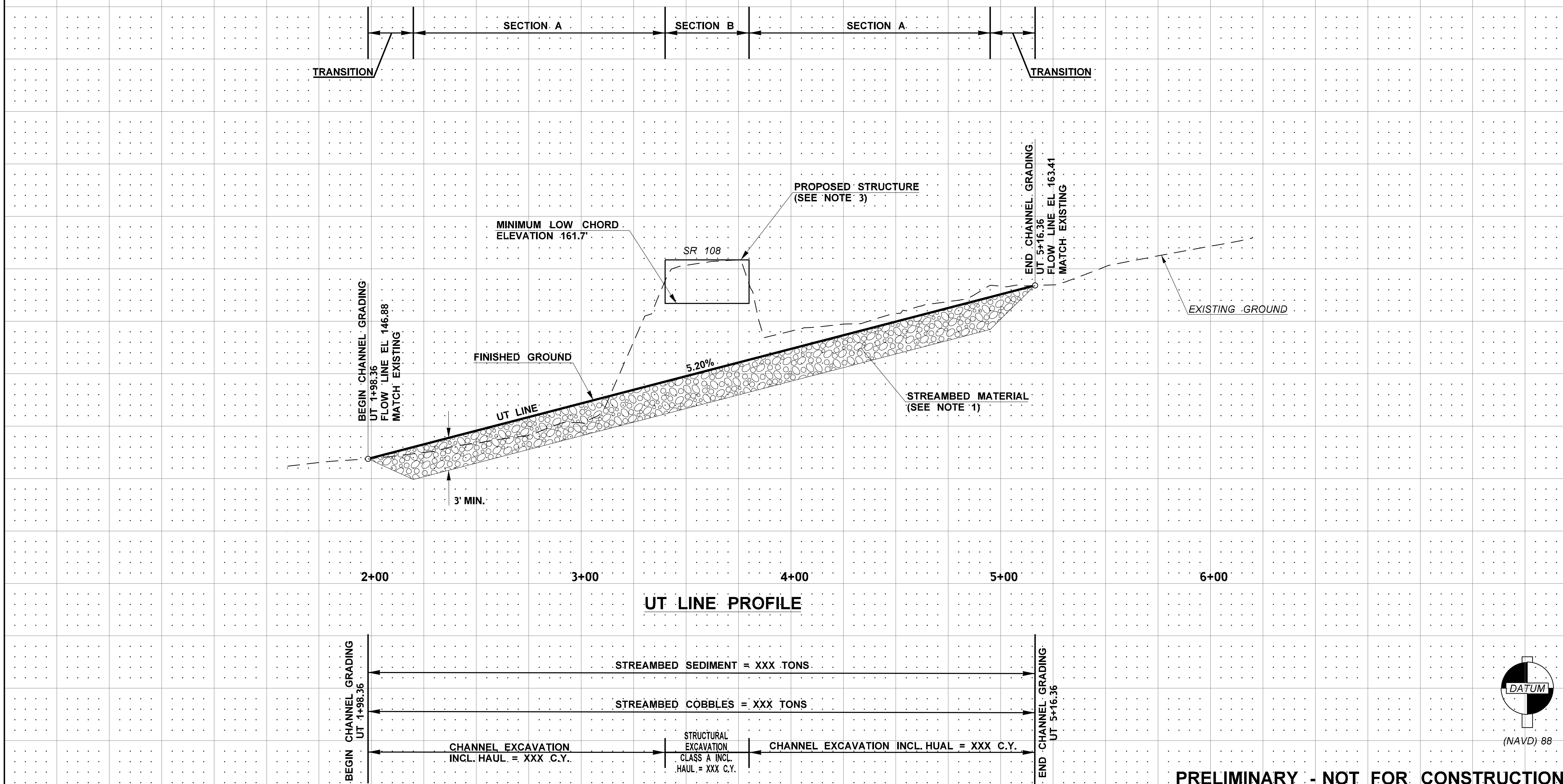
PLAN REF NO CR1

SHEET 2 OF 4 SHEETS

pw:\\HQOLYMAPPW03P.WSDOT.LOC:WSDOT\Documents_HQ\Fish Passage\ORproj\108\7.62_TribToSkookumCr2\Hydraulics_CAD_Sheets\StreamPlanPlanProfDetails\XL5950_PS_CR_001

NOTES:

1. SEE SPECIAL PROVISIONS "AGGREGATES FOR STREAMS, RIVERS, AND WATERBODIES FOR STREAMBED MATERIALS.
2. SEE SHEET CD1 FOR STREAM SECTIONS.
3. PROPOSED STRUCTURE SHOWN FOR ILLUSTRATIVE PURPOSES ONLY, STRUCTURE TYPE, SIZE, AND LOCATION TO BE DETERMINED DURING LATER PHASE OF DESIGN.



UT LINE PROFILE

PRELIMINARY - NOT FOR CONSTRUCTION

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DESIGNED BY	S. BEVAN
ENTERED BY	C. WILCOX
CHECKED BY	J. HEILMAN
PROJ. ENGR.	J. METTLER
REGIONAL ADM.	J. WYNANDS

REVISION	DATE	BY

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	

JOB NUMBER XXXXX

CONTRACT NO.

LOCATION NO. XL5950

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

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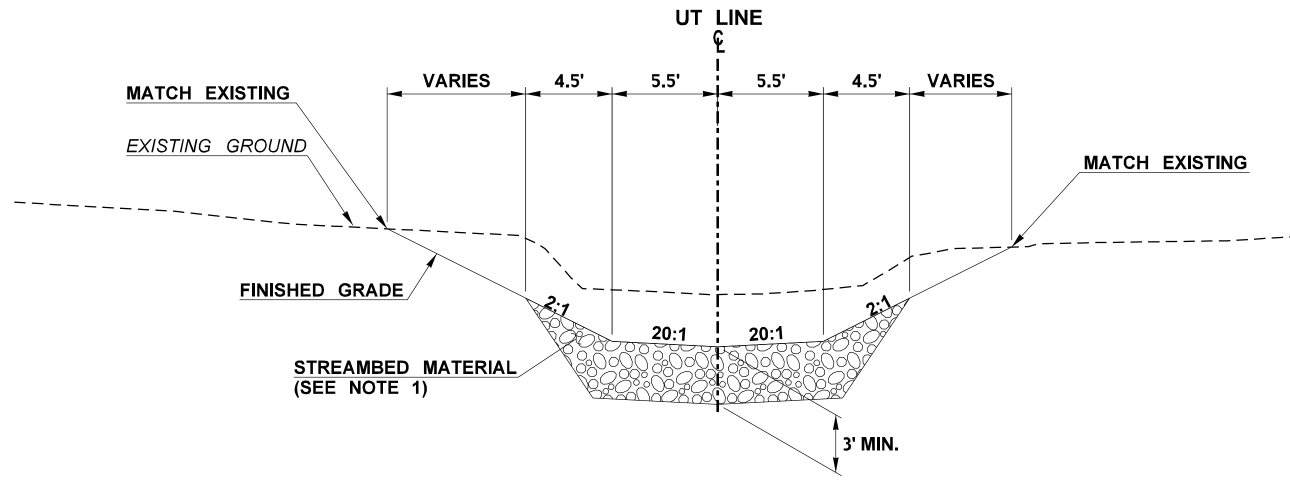
STREAM PROFILE

PLAN REF. NO. CP1

SHEET 3 OF 4 SHEETS

pw:\\HOOLYMAPPPW03P.WSDOT.LOC:WSDOT\Documents_HQ\Fish Passage\ORproj\108\7.62_TribToSkookumCr2\Hydraulics_CAD_Sheets\StreamPlanProfDetails\XL5950_PS_PR_CP_001



SECTION A

STATION
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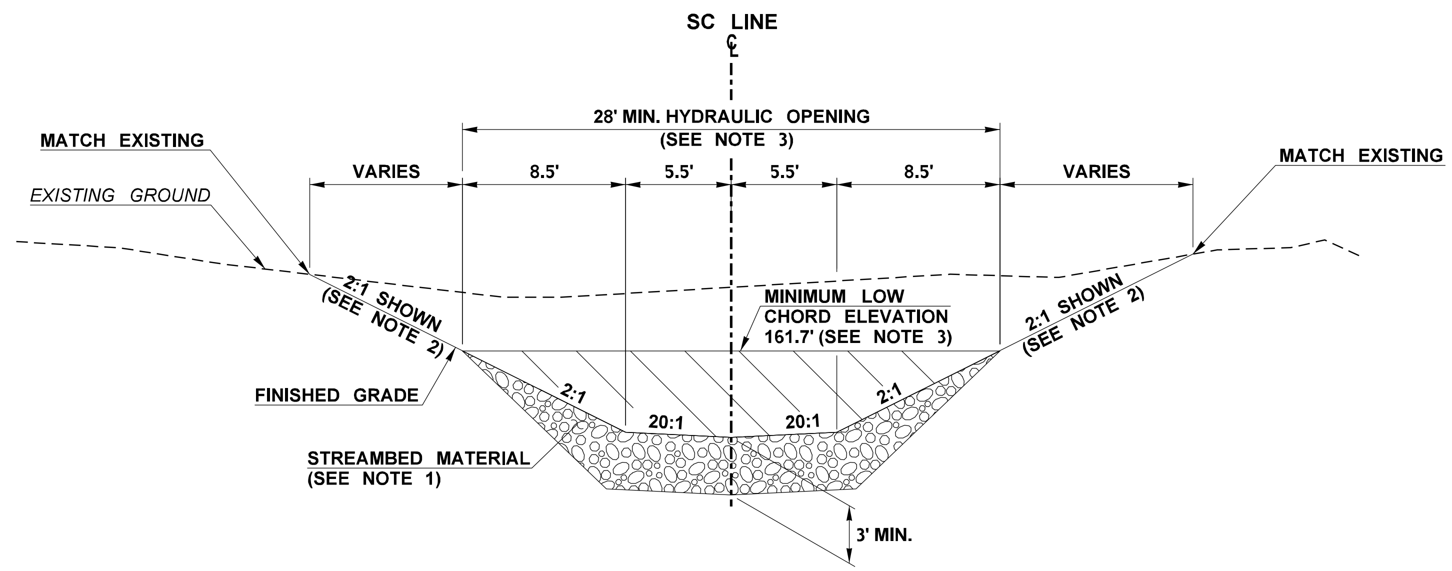
UT 3+80.00 TO 4+95.00



SECTION A

STATION
UT 3+40.00 TO 3+80.00

NOTES:

1. SEE SPECIAL PROVISIONS "AGGREGATE FOR STREAMS, RIVERS, AND WATERBODIES" FOR STREAMBED MATERIAL.
2. SLOPES SHOWN OUTSIDE HYDRAULIC OPENING ARE FOR ILLUSTRATIVE PURPOSES ONLY TO DEPICT ESTIMATED AREA OF POTENTIAL IMPACT. FINAL AREAS OF IMPACT TO BE DETERMINED PENDING GEOLOGICAL AND STRUCTURAL INVESTIGATION, STRUCTURE TYPE AND STRUCTURE LOCATION.
3. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO MINIMUM OPENING SHOWN ON PLAN.

PRELIMINARY - NOT FOR CONSTRUCTION

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DATE	5/20/2020
PLOTTED BY	CWILCOX
DESIGNED BY	S. BEVAN
ENTERED BY	C. WILCOX
CHECKED BY	J. HEILMAN
PROJ. ENGR.	J. METTLER
REGIONAL ADM.	J. WYNANDS

REVISION | DATE | BY

REGION NO. 10 | STATE WASH | FED.AID PROJ.NO.

JOB NUMBER XXXXX

CONTRACT NO. | LOCATION NO. XL5950

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STREAM DETAILS

PLAN REF NO CD1

SHEET 4 OF 4 SHEETS

Appendix C – WDFW Future Projections for Climate-Adapted Culvert Design Printout

Future Projections for Climate-Adapted Culvert Design

Project Name: 991672

Stream Name:

Drainage Area: 88 ac

Projected mean percent change in bankfull flow:

2040s: 15.8%

2080s: 21.4%

Projected mean percent change in bankfull width:

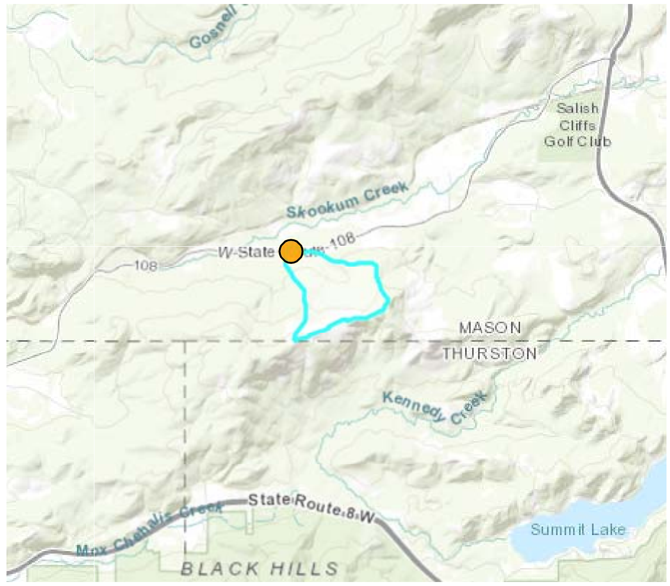
2040s: 7.6%

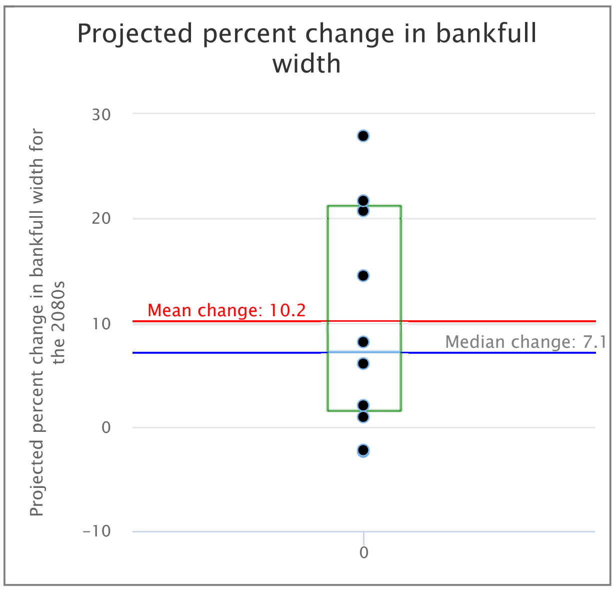
2080s: 10.2%

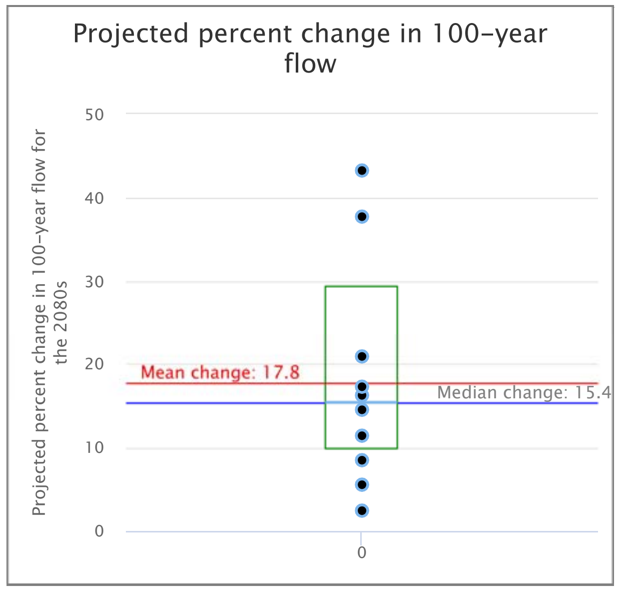
Projected mean percent change in 100-year flood:

2040s: 9.4%

2080s: 17.8%







Black dots are projections from 10 separate models